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Preliminary Analysis of the Heating of Ordnance in Ship Magazines Due to a Fire in an Adjacent Compartment

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for the
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FOREWORD

A computer code has been written to calculate heating into any magazine, given a specified fire size and location in an adjacent compartment. The various effects of compartment dimensions and fire parameters are analytically examined in this report. The program and report are provided as information and to serve as a point of departure and guidance for further work.

The analysis program, funded under contract N60530-89-M-B115, was sponsored by the Insensitive Munitions Technology Transition Program (IMTTP). The work was done by Joe Mansfield of JM Technical, 531 NW Canyon Drive, Redmond, Oregon (phone number: (541) 923-3627).

This report has been reviewed for technical accuracy by Martha Norris and Don Thompson.

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(U) This report documents a computer code written to calculate heating into any ordnance magazine, given a specified fire size and location in an adjacent compartment.

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PREFACE

This report provides an engineering tool for use as a starting point in the analysis of ordnance fires aboard Navy ships (fires within steel-walled compartments). The program is designed as a low-cost, first-cut evaluation of fire scenarios for the purpose of achieving insight, and thus guidance in establishing test matrices needed to identify and quantify compartment fire parameters, such as fire size, flame temperature fire duration, fuel consumption rate. Equations for the model used are incorporated in the program. The program is written in an interactive format.

The constants used in the computer program were derived based on the author's experience in this field. The constants should be considered as a best estimate and starting point, and then varied to determine the criticality of each specific parameter.

This document is published to disseminate the information and methodology used as an analysis tool for insight on the shipboard fire environment. Mr. Mansfield is willing to discuss his program with any interested caller.

This report is released at the working level for information only, and does not necessarily reflect the views of NAWCWPNS.

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SECTION 1

INTRODUCTION

The heating of ordnance in ships magazines due to a fire in an adjoining compartment was examined in a highly limited manner some time ago, as described in Reference 1. The purpose of that study was in part to establish the conditions (if any) that would lead to either "slow" or "fast" cookoff of ordnance, and the study did show circumstances that would probably result in cookoffs of either type. The study was particularly useful in revealing that the factors that govern ordnance heating are extensive and in some respects complex, and that comprehensive understanding and reliable prediction of ordnance heating would require a substantially more detailed analysis. The work described in this report represents the first stage of a comprehensive analysis. The purpose of the work described below was to: (1), identify the factors that govern ordnance heating, (2), determine the uncertainty level of the key factors, and (3), determine ordnance heating exposure estimates under various conditions.

The analysis of ordnance heating required the development of a computer program, which will be referred to as "MFIRE".* This program introduces energy (heat) into the fire compartment according to any selected fire size, and follows the heat transfer into and through the adjoining compartments; that is, the magazine and other compartments that collectively surround the fire compartment. The program calculates the temperature with time of the "gases" within these compartments and of all walls (bulkheads, decks and overheads) of the various compartments.

For a number of likely circumstances in the compartment system, the predominant heat input to the ordnance will be thermal radiation emitted from the bulkhead that separates the magazine and fire compartment, hereafter referred to as the "common" bulkhead. The temperature with time of this bulkhead is then important to ordnance heating evaluation, and the computer program has been set up to determine the consequent radiant heat input to each point on the surface of any cylindrical ordnance at any location within the magazine. Convection due to magazine gas flow over the ordnance surface will also contribute to ordnance heating (or cooling), and magazine gas temperature with time is thereby also an important result in evaluating ordnance heating.

The third parameter that is necessary to evaluate ordnance exposure concerns the ability of the magazine "gas" to absorb and emit thermal radiation. "Soot" will be generated in the magazine due to the heating of thermally degradable materials, such as the organic-based fire protection coating on the ordnance, bulkhead paint and other materials. Soot production can affect the

* The program is available upon request from the National Insensitive Munitions Information System (NIMIS-II). Inquiries may be directed to the Insensitive Munitions Office, Naval Air Warfare Center Weapons Division, China Lake, CA 93555-6001. A listing of the program is given in Appendix A. MFIRE is written in Fortran F77, and a 386 personal computer is adequate for its execution. Everything needed to operate in the program is written in the program. Every input is given in detail and defined. An operators manual is not needed.

temperatures achieved in the compartment system (walls and gases) as well as the mode of heat transfer to the ordnance. Regarding the mode of transfer, as the concentration of soot increases in the magazine, the radiant transfer from the bulkhead to the ordnance decreases due to absorption by the soot; however, there can be heat transfer to the ordnance due to radiation from the soot (as well as convection transfer from the magazine gas). Thus, it becomes important to evaluate the ability of soot to absorb radiation (the radiant absorption coefficient or extinction coefficient of the soot cloud) and to emit radiation (the emissivity and temperature of the soot cloud).

In summary, ordnance heating will depend on the temperatures of the common bulkhead and magazine gas and on the absorbing and emitting properties of the magazine gas. The results given in this report largely show the dependence of the bulkhead and magazine gas temperature on the governing factors of fire size, magazine and compartment sizes, soot concentration, and so on. It also shows the distribution of heat input along the surface of the ordnance due to radiation from the bulkhead for various ordnance locations. It does not at this time show the temperature response of ordnance to these heating inputs.

The results presented in this report do not represent a complete analysis of ordnance heating. Certain aspects of the analysis will require expansion or refinement, as noted throughout the report. A part of the purpose of the work was to identify where refined analysis is and is not necessary. However, the analysis at this stage does provide a very reasonable "picture" of ordnance heating levels.

SECTION 2

RESULTS OF ORDNANCE HEATING ANALYSIS

2.1 CONFIGURATION AND NOMENCLATURE OF COMPARTMENT SYSTEM

The two primary compartments of the analysis are the compartment containing the fire (the fire compartment) and the magazine. The wall shared by the fire compartment and magazine will be referred to as the "common bulkhead".* For purposes of discussion in this report, the horizontal dimension of the common bulkhead will always be designated as a "width" (the fire compartment width or the magazine width), as shown in Figure 1a. Fire compartment length and magazine length, then, will be in a direction perpendicular to the common bulkhead surface.

Ordnance heating is also affected by the compartments that immediately surround the fire compartment, and these adjoining compartments, designated "adjacent compartments", are included in the analysis. For purposes of analysis, then, the compartment system is as illustrated in Figure 1b, comprising of a fire compartment, magazine and several (usually five) adjacent compartments.

On ships, it will often occur that a magazine width will be different than the adjoining compartment width; for this case, it is noted that the width of the bulkhead that is shared by the magazine and the fire compartment is still referred to as the common bulkhead, that is, the common bulkhead is the smaller width of the two. Since ordnance heating depends on the relative widths of these two compartments, cases of differing width have been included in the analysis.

A difference in height of a magazine and its adjoining compartments appears to be relatively infrequent (on the basis of a limited ship survey), and the analysis is restricted to the common height of 10 feet.

2.2 FORMAT OF RESULTS

There are three components of ordnance heating: (1), radiation from the bulkhead, (2), radiation from the magazine gas (soot cloud), and (3), convection from (or to) the magazine gas. Ordnance heating depends largely, then, on the temperatures of the bulkhead and the magazine gas, as well as the absorption coefficient and emissivity of the magazine gas. Results are consequently given primarily in terms of the dependence of bulkhead and magazine gas

* Bulkheads and structures were assumed to be mild steel.

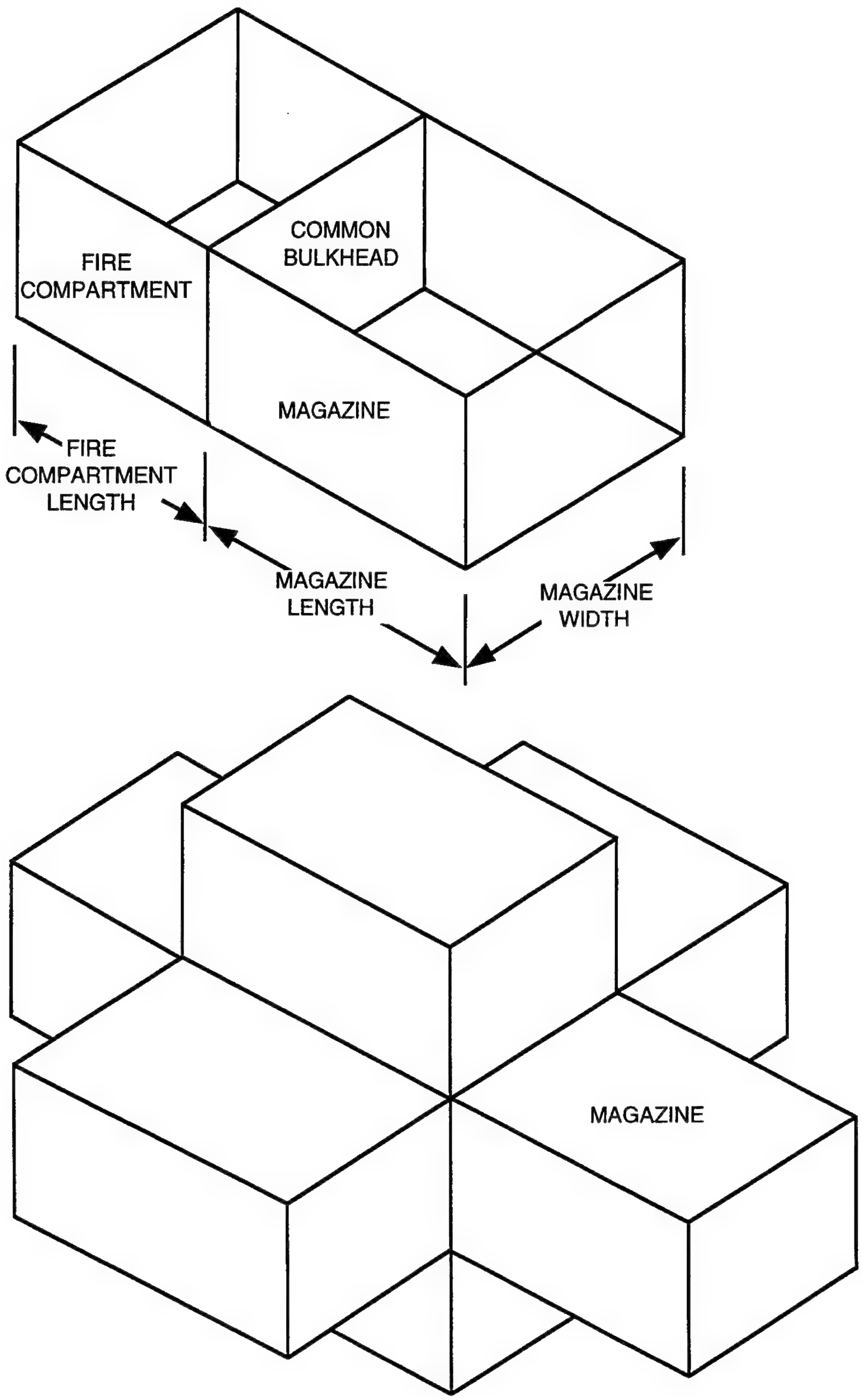
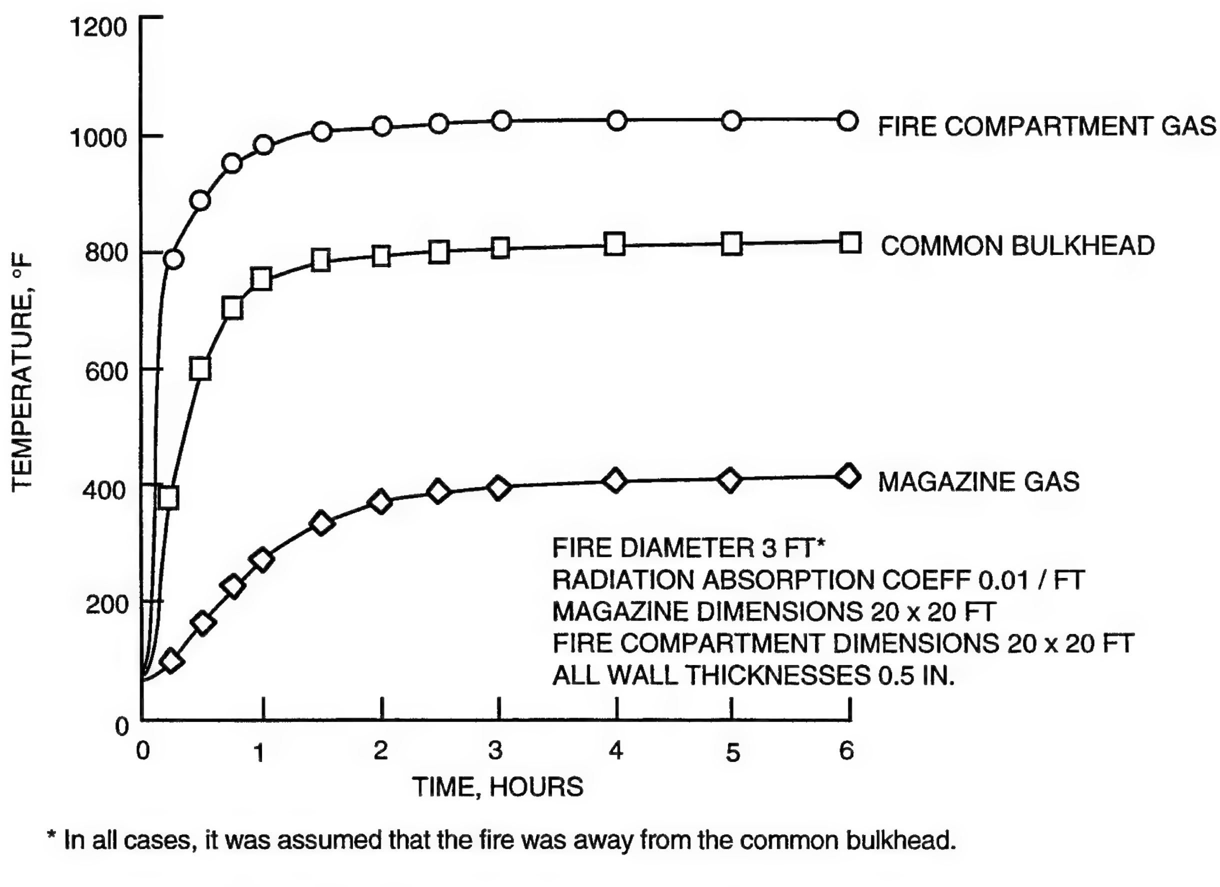


FIGURE 1. Configuration of Heating Analysis.

temperature on the various governing factors such as compartment size, fire size, radiant absorption coefficient and emissivity, ordnance position, and so on.

It is characteristic of the compartment system temperatures to "gradually" rise to constant or equilibrium values. An illustration of this characteristic is given in Figure 2, which shows the temperature with time of the fire compartment gas, the common bulkhead and the magazine gas for a particular set of conditions. Both the temperature rise rate and equilibrium temperature of the common bulkhead and magazine gas are important to ordnance heating. The equilibrium temperature is important because it will determine the temperature that the "explosive or reactive material" of the ordnance (the charge) will ultimately reach. The rate of temperature rise is important because it will determine the temperature gradient in the charge, and in turn determine whether the ordnance response will be a "slow" or "fast" cookoff. In order to expediently show the dependence of bulkhead and magazine gas temperature on the governing factors, the results are primarily presented in terms of equilibrium temperatures and the times to reach 90 percent of the equilibrium temperature. It is noted, however, that the complete tabulated temperature-time output of the program MFIRE is given for a number of cases in Appendix B.



* In all cases, it was assumed that the fire was away from the common bulkhead.

FIGURE 2. Temperature Versus Time of Compartment System Components.

2.3 THE EFFECT OF COMPARTMENT DIMENSIONS

Fire compartment gas temperature will rise after fire initiation until the total rate of heat loss from the compartment equals the rate that energy is supplied by the fire. The two primary mechanisms of heat loss are through hot gas escape from the fire compartment and heat transfer through the walls (bulkheads, overheads and deck) of the fire compartment. It would then be expected that increases in the wall surface area would reduce the equilibrium temperature of the gas in the fire compartment, and in turn that the temperatures of the common bulkhead and magazine gas would decrease. This effect is illustrated for a variation in fire compartment length in Figure 3.

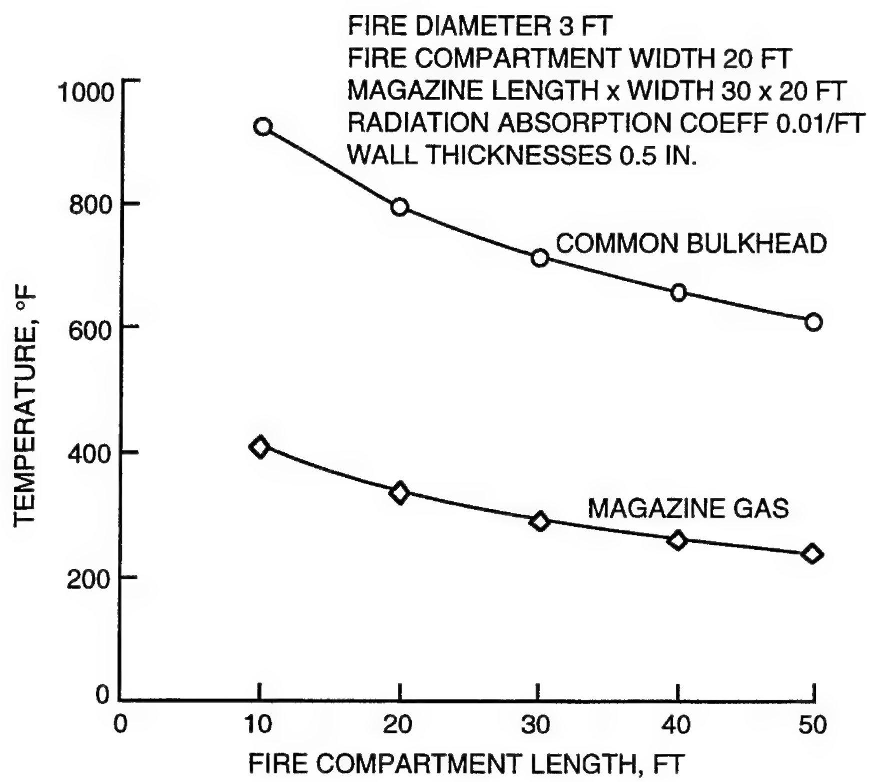


FIGURE 3. Equilibrium Temperature Versus Fire Compartment Length.

Fire compartment length also has a significant effect on the temperature rise rate of the bulkhead and magazine gas. The times for the bulkhead and magazine gas to reach 90 percent of their equilibrium temperature for various compartment lengths is listed in Table 1. It can be seen that the times increase substantially with increasing length.

TABLE 1. Time to 90% of Equilibrium Temperature Versus Fire Compartment Length.

		Fire compartment length, ft.				
		10	20	30	40	50
Time, hours	Common bulkhead	0.59	0.83	1.0	1.2	1.4
	Magazine gas	1.7	2.1	2.4	2.7	2.8

The effect of changes in magazine length is somewhat different than for fire compartment length. The effect of magazine length is illustrated in Figure 4. It can be seen that the common bulkhead temperature is nearly invariant, while the magazine gas temperature decreases with increasing length in much the same manner as for changes in fire compartment length. The change in response time (not listed) was negligible for both temperatures.

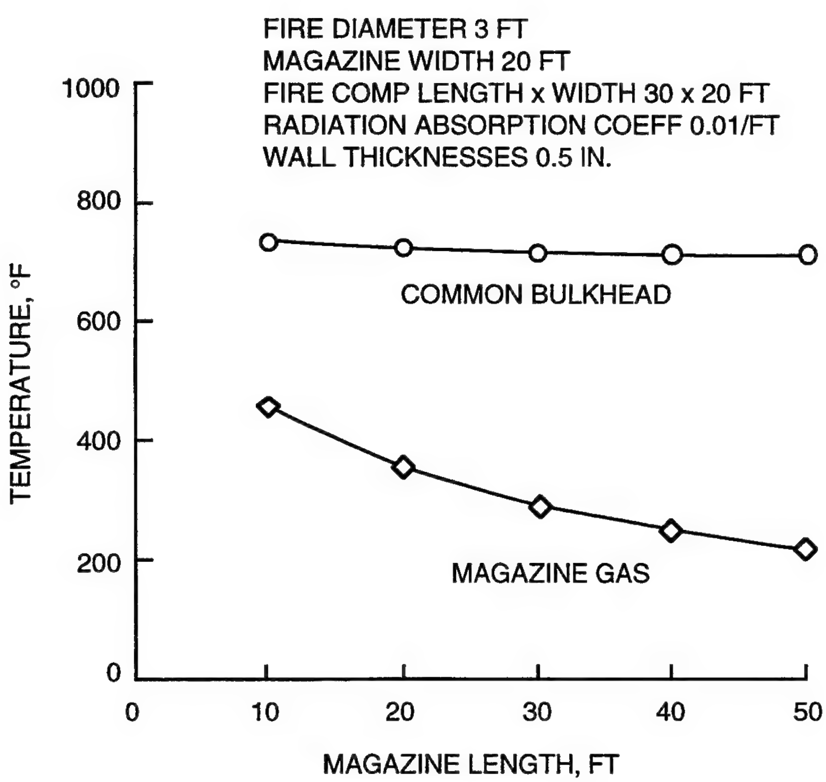


FIGURE 4. Equilibrium Temperature Versus Magazine Length.

Accounting for the behavior of the magazine gas temperature appears to be straightforward. Heat entering the magazine through the common bulkhead is essentially invariant. The temperature of the magazine gas will rise until the total heat transfer from the gas to the magazine walls equals the heat input. As the magazine surface area increases, the transfer from the gas will equal the input at a lower gas temperature.

While accounting for the bulkhead temperature is more involved, it is instructive to explore the reasons for its invariance. Changes in magazine length only change the heat loss boundary conditions of the common bulkhead, and the common bulkhead comprises only a small fraction of the surface area of the fire compartment (in this case, 9 percent). Thus, one may conclude first that a magazine length change cannot greatly influence the temperature of the fire compartment gas, and the heating exposure of the common bulkhead from the fire compartment side does not thereby change appreciably.

Second, the heating feedback from the magazine to the common bulkhead is not significant. For example, the walls of the magazine do not achieve sufficient temperature to appreciably radiate back to the common bulkhead. Also, radiation from the magazine gas to the common bulkhead is not significant, particularly in this case where the magazine gas is nearly transparent (non-emitting). Finally, there is the comparatively small influence of convection between the common bulkhead and magazine gas. (This small total feedback is true for many situations.) Thus, heat transfer on both surfaces of the common bulkhead is not greatly changed, and the bulkhead temperature is consequently relatively constant.

The above comments appear to imply that a change in all (or most) of the compartments surrounding the fire compartment should cause a more significant change in system temperatures, and it is convenient to digress to the effect of these dimensions. Results from changes in the dimensions of the adjacent compartments are listed in Tables 2 and 3; for each adjacent compartment, the surface shared by the fire compartment coincide in dimension with the fire compartment surface, so for each adjacent compartment the single dimension change was in a direction perpendicular to the shared surface.

The results given in Table 2 do show that fairly substantial changes occur in the temperatures of a given adjacent compartment due to dimension changes of all adjacent compartments. It is perhaps fair to say, however, that the temperatures are not particularly sensitive to changes in dimension. More importantly, it can be seen from Table 3 that the temperatures that determine ordnance heating are quite insensitive to adjacent compartment dimensions. Thus, the manner in which the magazine/fire compartment pair is arranged or located in the ship is not especially important.

TABLE 2. The Effect of Adjacent Compartment Dimension on Adjacent Compartment Temperatures.

		Dimension of adj. comp., ft.			
		10	20	30	40
Temp., °F	Bulkhead shared with fire comp.	778	730	707	693
	Gas in adjacent compartment	544	439	378	335
	Outer bulkhead of adjacent compartment	393	312	265	234

TABLE 3. The Effect of Adjacent Compartment Dimension on Magazine Temperatures.

		Dimension of adj. comp., ft.			
		10	20	30	40
Temp, °F	Common bulkhead	721	696	684	677
	Magazine gas	295	281	275	272

Returning to magazine and fire compartment dimensions, the results presented above pertained solely to the effect of changes in the length of the magazine and fire compartment; as such, the dimensions of the common bulkhead were fixed. The results for width changes, but for the particular case where the widths of the magazine and fire compartment are equal, are given in Figure 5. The cause of the temperature trend for the common bulkhead shown in Figure 5 is reasonably straightforward. When the width of the common bulkhead is increased, the dimensions of the fire compartment ceiling, floor, common bulkhead and wall opposite the common bulkhead are all increased; for the 30 foot compartment and magazine lengths associated with Figure 5, for example, a common bulkhead width increase from 20 to 40 feet results in a surface area increase of the fire compartment of 73 percent. Thus, the energy from the fire is distributed over this substantially larger surface area, and a significant decrease of bulkhead temperature with increasing bulkhead width would be expected.

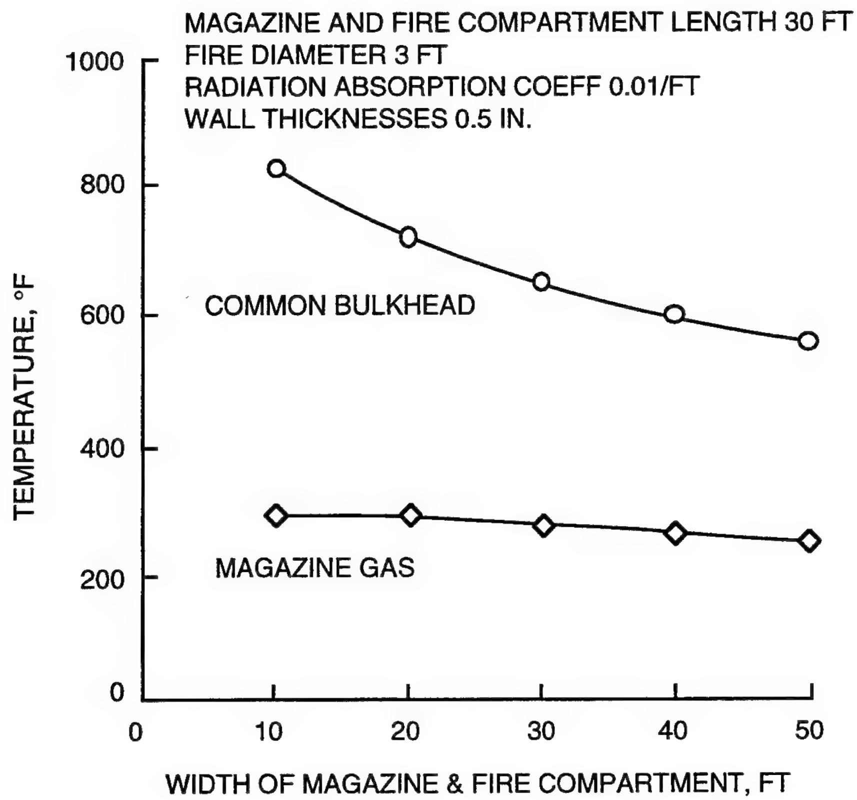


FIGURE 5. The Effect of Compartment Width on Equilibrium Temperature.

The reasons for the nearly constant behavior of the magazine gas temperature with changing width are perhaps somewhat less apparent. An important factor is that the ratio of the surface area of the common bulkhead to the total surface area of the fire compartment is nearly independent of the width of the common bulkhead; for the above case again of increasing the width from 20 to 40 feet, the surface area of the common bulkhead changes only from 10.5 to 9.1 percent of the total area of the fire compartment. While the magazine dimension change will also effect the energy loss from the magazine, it was shown above (Table 3) that the magazine gas temperature tends to be reasonably insensitive to magazine dimensions.

Width has a mild effect on response time, as seen in Table 4.

It can occur that the magazine width is either smaller or larger than the fire compartment width. When the magazine width is smaller, the temperature of the common bulkhead and the magazine gas, and the response time of those temperatures, are negligibly different than when the magazine width is increased to equal the fire compartment width. Thus, the data from all figures and tables given above can be applied to cases where the magazine width is smaller than the fire compartment width.

TABLE 4. Time to 90% of Equilibrium Temperature Versus Compartment Width.

		Fire comp. or mag. width, ft.			
		20	30	40	50
Time, hours	Common bulkhead	1.1	1.4	1.6	1.8
	Magazine gas	2.7	3.0	3.3	3.5

Calculations have not been done for the case where the magazine width is larger than the width of the fire compartment. In general, common bulkhead temperatures would not be significantly affected by extending the magazine bulkhead beyond the fire compartment. The magazine temperatures, however, would decrease significantly with increases in this extension.

2.4 THE EFFECT OF FIRE SIZE

A commonly used "rule of thumb" for liquid fuel pool fires is that the liquid fuel thickness decreases (by vaporization into the flame above) at a rate that is constant and independent of fuel layer surface area. Thus, fuel supply rate to the fire is directly proportional to the surface area of the fuel pool, and heat energy generated by the fire is to the first approximation also proportional to the surface area of the fuel pool. The results given below are based on this approximation.

Temperatures in the compartment system are quite sensitive to fire size. An illustration of the dependence of equilibrium temperatures on fire diameter (fuel pool diameter) is given in Figure 6. It can be seen that there are pronounced increases in fire compartment gas temperature and common bulkhead temperature with increasing fire diameter, and a somewhat less pronounced increase of magazine gas temperature. Fire size is clearly one of the critical factors of ordnance exposure. Fire size also affects the response time of the compartment system. For the common bulkhead and magazine gas, for example, it can be seen from Table 5 that the time to reach 90 percent of equilibrium temperature decreases significantly with increasing fire diameter.

A more extensive presentation of bulkhead and magazine gas temperature is given in Figures 7 and 8, respectively. These figures show the effect of variations in both fire diameter and compartment length. Two conclusions from these figures, which are recurring conclusions, are worth noting. It is apparent from these figures that ordnance can experience an extensive range of heating environments, and that a number of fire size/compartment length combinations (or combinations of other factors) lead to the same level of either radiant heating from the bulkhead or

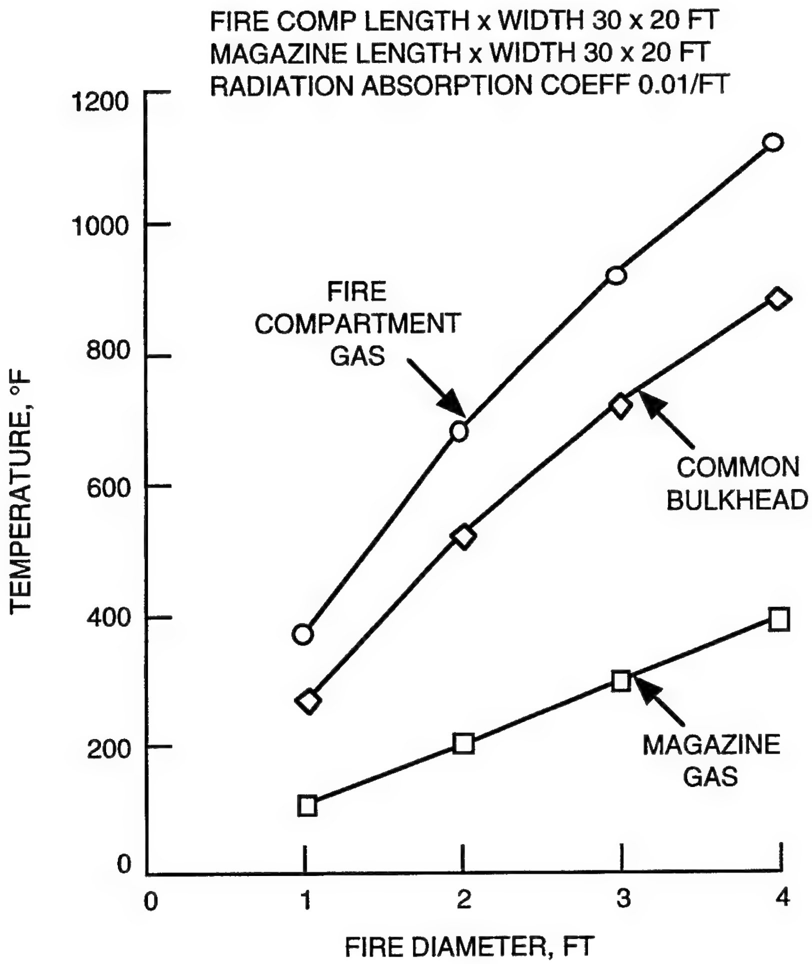


FIGURE 6. The Effect of Fire Diameter on Equilibrium Temperature.

TABLE 5. Time to Achieve 90% of Equilibrium Temperature Versus Fire Diameter.

		Fire diameter, ft.			
		1	2	3	4
Time, hours	Common bulkhead	3.0	1.7	1.0	0.73
	Magazine gas	3.4	3.1	2.4	1.9

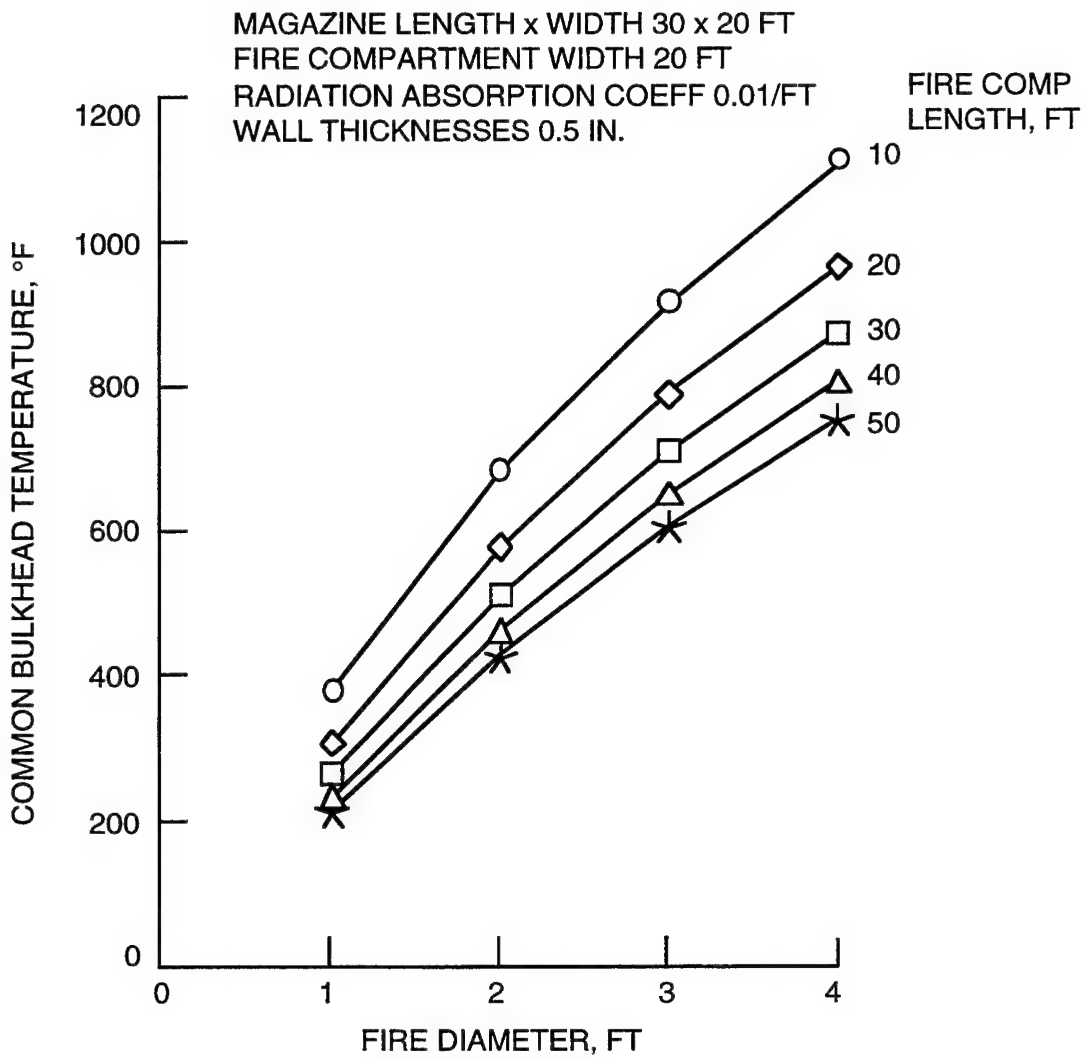


FIGURE 7. Common Bulkhead Equilibrium Temperature Versus Fire Diameter.

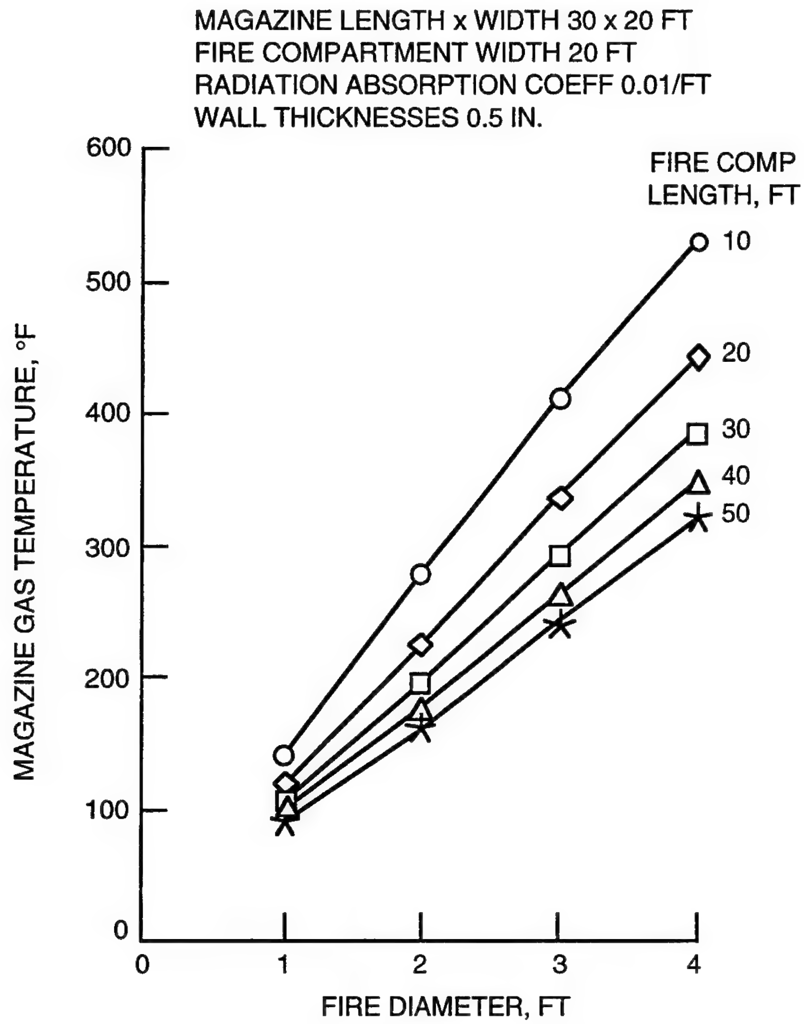


FIGURE 8. Magazine Gas Equilibrium Temperature Versus Fire Diameter.

transfer from the magazine gas. (The same applies to rates.) When these ordnance heating environments are applied to specific pieces of ordnance, it will be important to sort out the large number of circumstances that lead to the same ordnance response. Then, and only then, can the probabilities of given events begin to be evaluated.

The sensitivity of bulkhead and magazine gas temperature shows the importance of determining the fire sizes that are likely to occur. Fire sizes that can be sustained will depend in a complicated way on: (1), the sizes and locations of the air inlet and combustion product exit ports of the fire compartment, (2), the resistance to gas flow along both the inlet path from ship exterior to fire compartment and the exit path from the fire compartment to ship exterior, and (3), on the various conditions at the inlet and exit ports of the ship (e.g., wind speed and direction). It is anticipated that determining fire size for given sets of conditions through analysis would be

unacceptably unreliable. It is thought that the "compartment fire facility" at the Naval Air Warfare Center, China Lake, Calif., (or similar facilities) could be used to provide highly useful data.

2.5 ERRORS IN HOT GAS EXHAUST

An assumption has been used at this stage of analysis that the gas temperature in the fire compartment is uniform. A preliminary examination of the errors in temperature analysis caused by this assumption has been conducted and is discussed in this section.

There is a mixing process that occurs between the rising flame volume of the fire and the gas that surrounds the flame volume. As the flame volume rises, it causes entrainment of the surrounding gas into the rising flame, and there is a turbulent mixing of the combusting and combusted materials with the entrained gas. The entrainment and mixing tends to cool the rising plume. The flame and combustion product plume is also losing energy to the surrounding gas through radiation, which also tends to cool the plume as it rises. Under many circumstances, there is a fairly complete mixing before the gas reaches the exhaust port of the fire compartment, and the remaining unmixed gas will have approached the temperature of the surrounding gas by the time it reaches the exit port due to energy loss by radiation. For the results presented above, heat loss by hot gas flow through the exit port of the fire compartment has been accounted for under the assumption that the temperature of the exiting gas is the same as the surrounding gas within the compartment.

There can also be circumstances where the temperature of at least part of the exit flow is higher than the surrounding gas; there would then be an additional heat loss from the compartment not accounted for above, and the system temperatures would be lower than the values presented above. A circumstance that is favorable to compartment heat loss, for example, is where concurrently, the air inlet port is on the bulkhead near the floor and reasonably close to the fire, and the exit port is directly above the fire.

It is difficult to establish a clear cut value of additional heat loss for this case (or any other). Experimental results for large open fuel fires show thorough mixing and low temperatures (except for a small central core) at heights equivalent to three fire diameters (Ref. 2). Scaling to small internal fires (a scaling that has not been validated) would suggest that the additional heat loss effect would be small for fire diameters of three feet or less. While thorough calculation of heat loss is a sizable undertaking, crude estimates were made of radiation heat loss from the rising plume, and these results are revealing. Estimates for two and three foot diameter fires, for example, showed plume temperatures at exit within 50 and 200 degrees F, respectively, of the surrounding gas due to radiation loss alone. We next assumed that the entire exhaust flow was 200 deg F above the surrounding gas, and evaluated the effect on system temperatures. In this regard, fire compartment heat loss due to hot gas exhaust is a fairly small fraction of the total heat loss from the compartment (heat transfer through the walls is the predominant loss); for example,

in the three foot diameter case examined above, 15 percent of the heat loss from the fire compartment is due to exhaust. The 200 degree F increase in exhaust temperature then caused only a 3 percent additional rate of total heat loss. The effect on bulkhead and magazine gas temperatures for a range of additional heat loss percentages is given in Table 6 for the 3 foot diameter case.

TABLE 6. Effect of Heat Loss Due to the Exhaust of Unmixed Combustion Products.

	Additional heat loss rate, %			
	0	2	5	10
Bulkhead temp., °F	715	708	699	681
Mag. gas temp., °F	291	288	283	274

* This case is for a 3 foot diameter fire with length x width dimensions of both fire compartment and magazine of 30x20 feet.

It can be seen from Table 6 that system temperatures are not seriously affected by this error in exhaust temperature. It is thought that the issue should be examined with greater thoroughness than was done here (e.g., literature search for experimental results), but serious error in ordnance exposure from neglecting this error is not anticipated.

A similar error relates to the vertical gradient of gas temperature in the fire compartment. Ignoring the increasing temperature with distance from the floor will again cause a greater fire compartment heat loss through hot gas exhaust than is calculated. The magnitude and character of the fire compartment gradient is highly variable, and sensitive to a number of conditions including soot concentration, fire location with respect to the air inlet and exhaust locations, and the resulting gas temperature level. We have not been able to locate data that is considered useful to the ship problem, although the search has not been extensive. While serious errors are not anticipated from the assumption of zero gradient, it would not be surprising that further study would show that the desirability of incorporating gradient information into the calculation may be considered at least marginal. It is thought that incorporating a refined thermo-aerodynamic math model into the analysis is entirely inappropriate. In our judgment, a simple empirically based adjustment to the gradient is more suitable. It is thought, once again, that the fire compartment facility at China Lake could provide very useful data.

2.6 THE EFFECT OF WALL THICKNESS

The thickness of walls (bulkheads, decks and overheads) throughout the compartment system will not affect equilibrium temperatures of the system, but thicknesses will have an impact (in some cases a large impact) on the time to reach given temperatures. The effect of wall thickness on the temperature response of the common bulkhead is illustrated in Figure 9, which shows the temperature with time for two fire compartment wall thicknesses. It is evident from a comparison of the two curves that the rate of ordnance heating and the temperature gradients in the ordnance would be distinct in the two cases.

The effect of fire compartment wall thickness on the time for the common bulkhead to reach 90 percent of its equilibrium value is illustrated in Figure 10. There is a pronounced and nearly linear increase of time with increasing wall thickness; very simply, it takes more time for the fire to heat a thicker wall. The effect of increasing wall thickness of the magazine and adjacent compartments is not included in Figure 10 because the effect is not significant. The reason that the thickness of the outer walls does not influence the rise rate of the fire compartment walls is because there is very little heat transfer feedback from the magazine and adjacent compartments to the fire compartment (the lack of feedback was explained above).

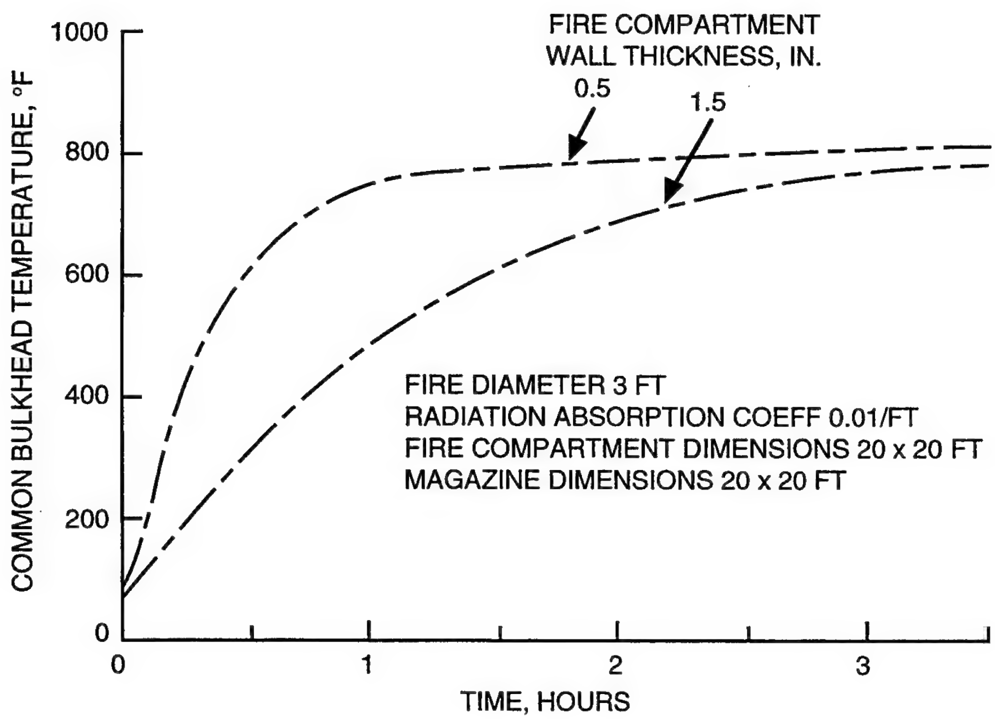


FIGURE 9. The Effect of Wall Thickness on Time Response.

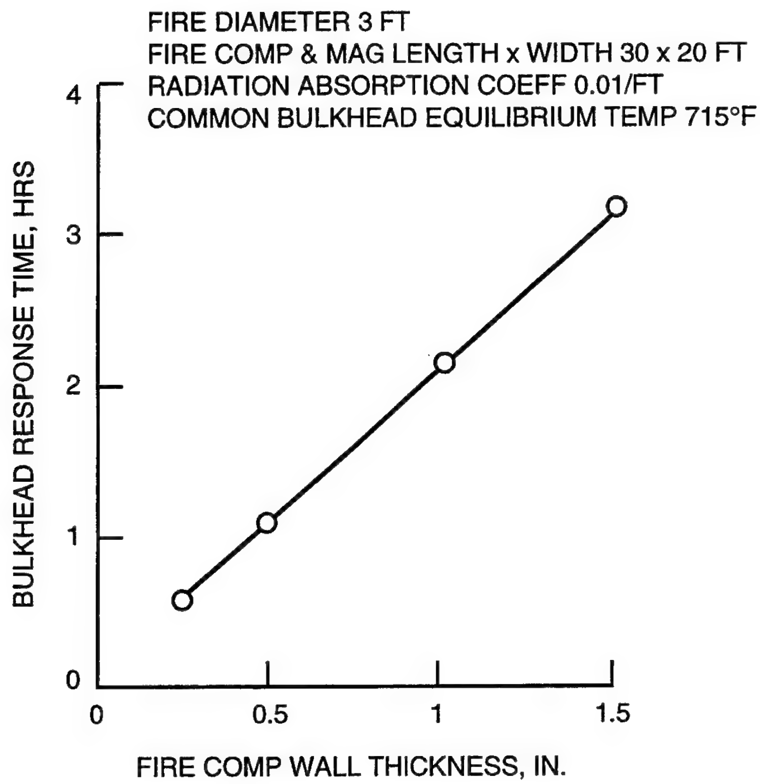


FIGURE 10. Response Time of Bulkhead Versus Wall Thickness.

The temperature rise rate of the gas in the magazine (and in the adjacent compartments) is in contrast affected by the wall thicknesses of the magazine, the adjacent compartments and the fire compartment. This is illustrated in Figure 11. Figure 11 also shows that it can take as long as 8 hours for the magazine gas to approach equilibrium temperature for the thicker wall cases. These times will be longer for smaller fires and larger compartments.

It is mentioned that ship compartment surfaces usually comprise "I" beam or "T" sections welded to flat sheet, while the basis of results given in this report are for flat sheets. In many cases the presence of the stiffeners will affect the results, particularly the times to reach given temperatures and the radiation view factors of the ordnance. In our judgment, the anticipated magnitude of errors warrants upgrading the analysis for a number of cases.

2.7 THE EFFECT OF SOOT GENERATION IN THE MAGAZINE

Magazines usually contain materials that decompose on heating to produce soot. These materials include the organic-based ordnance coatings, bulkhead paint, and any plastic or organic

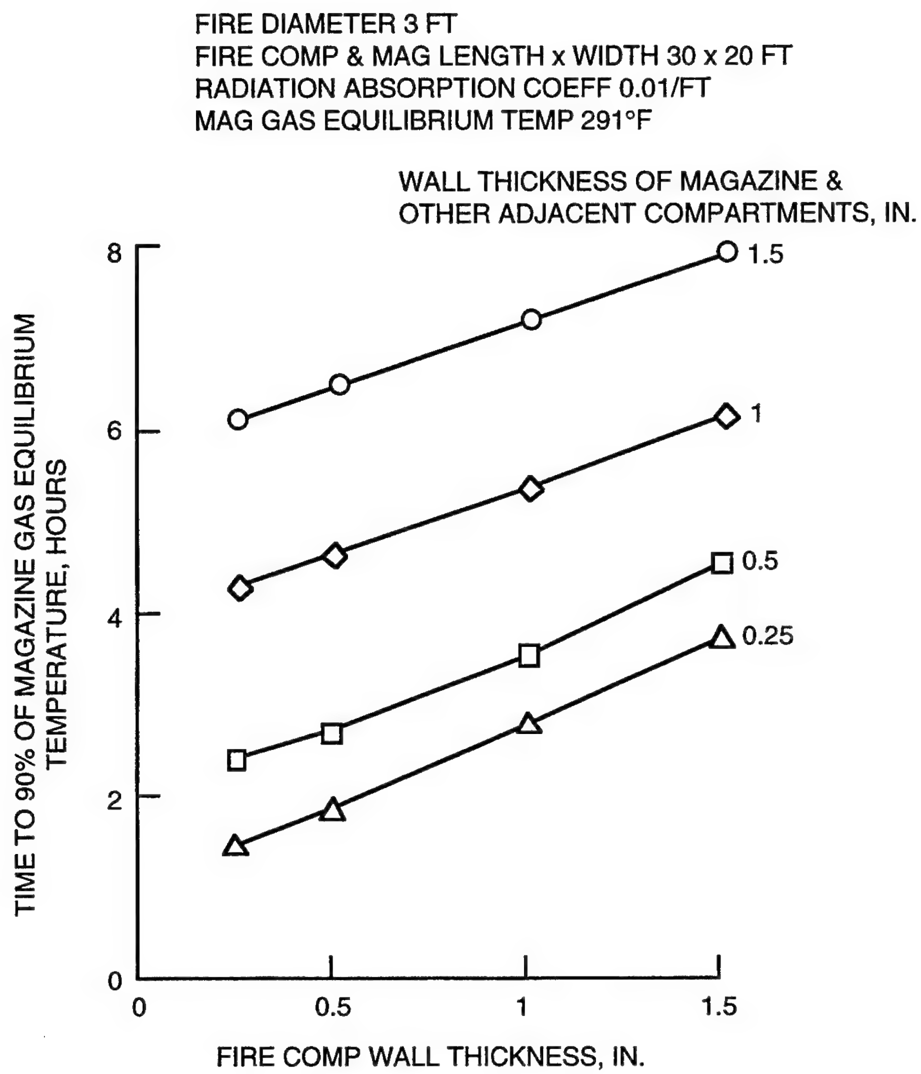


FIGURE 11. Time Response of Magazine Gas Versus Wall Thickness.

materials (e.g., crating materials). Soot generation is important because it can affect the temperatures of the compartment system and because it can affect the mode (and thereby the magnitude) of heat transfer to the ordnance.

Although it was not evident before the analysis, it turns out that compartment system temperatures are not sensitive to the quantity of soot produced; plots illustrating the dependence are included below. The mode (and level) of ordnance heating is another matter. With the presence of soot, there will be a contribution to ordnance heating through radiation from the soot particles to the ordnance surface. As the soot concentration increases, radiation from the

common bulkhead will be increasingly absorbed by the soot (thus reducing ordnance heating due to radiation from the bulkhead), and radiation from the soot to the ordnance will tend to be an increasing component. If the soot concentration becomes sufficient, there can in fact be a transition in the primary mechanism of ordnance heating from wall radiation to radiation from soot in the "vicinity" of the ordnance. It is noted, too, that radiation from the bulkhead primarily exposes one side of the ordnance cylinder, whereas soot radiation is to the entire ordnance surface (except as crating prevents exposure).

Soot production is generally a complex process. As the temperature of the organic solid rises, chemical breakdown of the organics causes hydrogen and the volatile hydrocarbon fragments to outgas from the surface of the solid. The outgassed hydrocarbons can decompose (pyrolize) further to form carbon or fragments of high-carbon content, or the hydrocarbons can enter the combustion reaction to the extent that oxygen is available (oxygen will tend to become scarce with time unless supplied, for example, through a venting system). The carbon or high-carbon fragments then condense to form soot.

There is a sizable quantity of data available with regard to soot production under conditions similar to that described above (Refs. 3, 4, and 5). The data tends to be of two types. Some studies identify the dependence of the type of outgassing chemical species on the type of material being heated and the temperature of the material. This is useful in providing a means of estimating soot production with time in the magazine. Other studies provide indicators of the absorption of radiation by the soot produced from a heated sample. While this type of study provides a direct measure of radiant absorption, the temperature or temperature profile of the sample is usually not well defined. It is possible that an extensive literature survey will provide data that are adequate to the purposes of this project. It is thought to be more likely, however, that predictions at a reasonable level of confidence will require testing with samples which duplicate the magazine materials under conditions that reasonably resemble those in the magazine.

We have made rough estimates of soot quantities or soot concentrations that would likely be produced in the magazine. The quantity of degradable materials present can vary substantially from magazine to magazine and from time to time in the same magazine; for example, a given magazine may contain little or no ordnance with coatings, or be packed with coated ordnance. Consequently, a broad range of soot concentrations can occur.

It appears that the variation can range from concentrations that will produce no significant radiant transfer to the ordnance to concentrations that may cause soot radiation transfer to predominate. In terms of radiation absorption coefficient, values from 0.0001/foot to 1/foot appear to be possible. A sense of these coefficients is given in Table 7.

In addition to absorption coefficient, the emissivity of the soot cloud must be determined because the heat transfer to the ordnance is proportional to the emissivity (and also because the heat transfer to the magazine walls depends on the emissivity).

TABLE 7. Rough Meaning of Absorption Coefficient.

Absorption coeff., 1/ft.	Visibility
0.00001	Mildly smoggy day
0.0001	Very smoggy day
0.001	See across room
0.01	Can't see across room
0.1	Trouble seeing hand
1	Typical for flame region of open pool fire

Both the absorption coefficient and the emissivity increase as the soot concentration increases, and the two are related. The dependence of emissivity on the properties and concentration of soot is quite involved, and fortunately has been well evaluated by Stull and Plass (Ref. 6). Reference 6 shows that the emissivity depends on a number of factors, which include the soot particle concentration, the particle size (or size distribution), the wavelength distribution of emitted radiation, and, usually, the distance between the irradiated surface in questions (the ordnance) and the boundary of the soot cloud (in our case, the common bulkhead). We have assumed a uniform particle diameter of 0.1 micron, and on the basis of Reference 6, and on the basis of an approximate scheme for evaluating the dependence of the absorption coefficient on soot concentration, the relationship between absorption coefficient and emissivity was determined. The relationship was then incorporated into the computer program MFIRE.

Compartment system equilibrium temperatures were then calculated for a number of selected absorption coefficients and corresponding emissivities. An illustration of these results is given in Figure 12. It can be seen from Figure 12 that the temperature of the fire compartment gas and the common bulkhead have little dependence on the concentration of soot. The magazine gas temperature shows a small but "odd" dependence over the coefficient range 0.01 to 1.0/ft. It is noted that the extraction and development of the relationship between the coefficient and emissivity from Reference 6 was somewhat "awkward" and laborious, involving the solution of simultaneous equations for each small interval of the coefficient. We chose to use linear approximations over each interval, with the risk that the errors produced in temperature evaluation could be unacceptable if the temperature was particularly sensitive to the ratio of coefficient to emissivity. It will be seen below that the magazine gas temperature is highly sensitive to this ratio. For the present, we reserve judgment regarding the realism of the behavior of the magazine gas temperature.

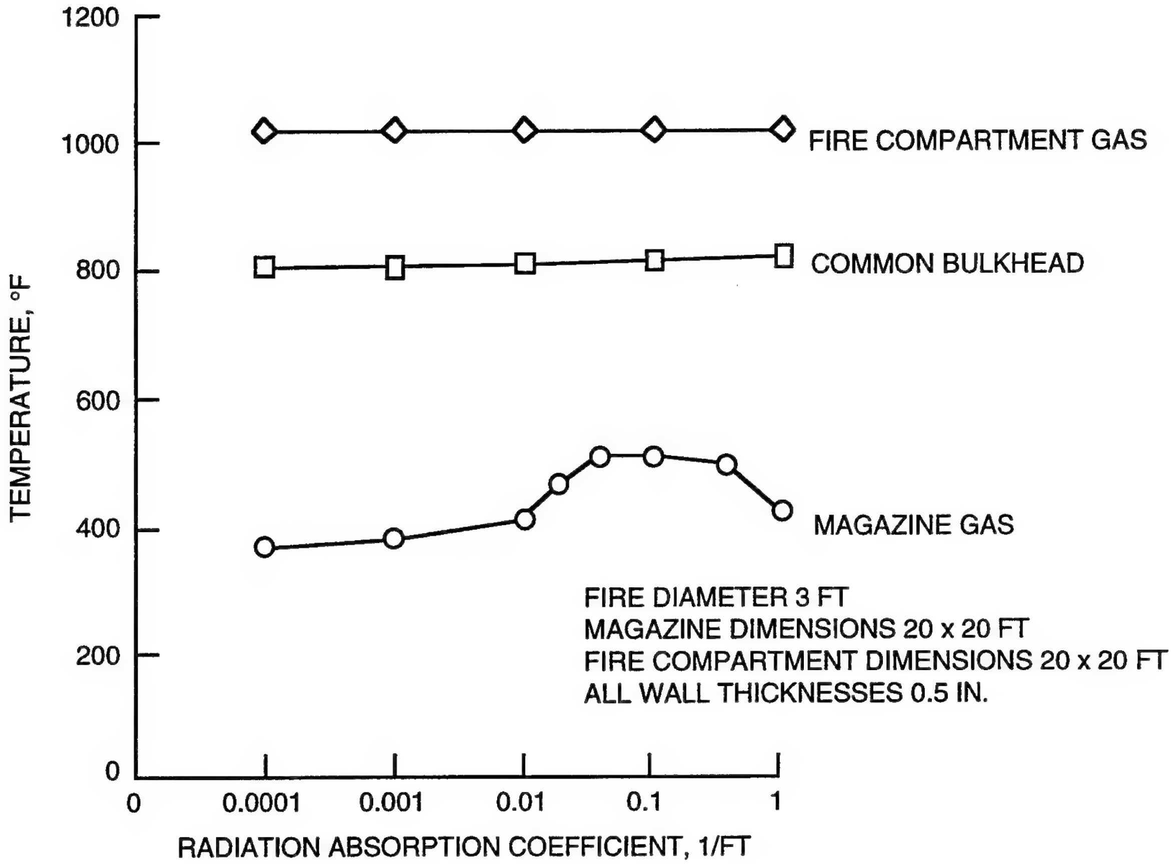


FIGURE 12. The Effect of Magazine Soot on System Equilibrium Temperatures.

In addition to the possible calculational error described above, the above ratio can be misevaluated for the magazine circumstance for a number of reasons, not the least of which is the uncertainty of the soot particle size distribution. For this reason, compartment system temperature was evaluated for a range of ratios of coefficient to emissivity (ratios that departed from the value determined from the incorporated relationship). An illustration of the results of these calculations is given in Figure 13. For this figure, for a particular coefficient of 0.01/foot, emissivity values were used which departed above and below the normal value. It can be seen from Figure 13 that the magazine gas temperature is highly sensitive to this ratio. Thus, a factor has been identified which can significantly affect the result, and it is clear that the relationship should be re-examined with particular care.

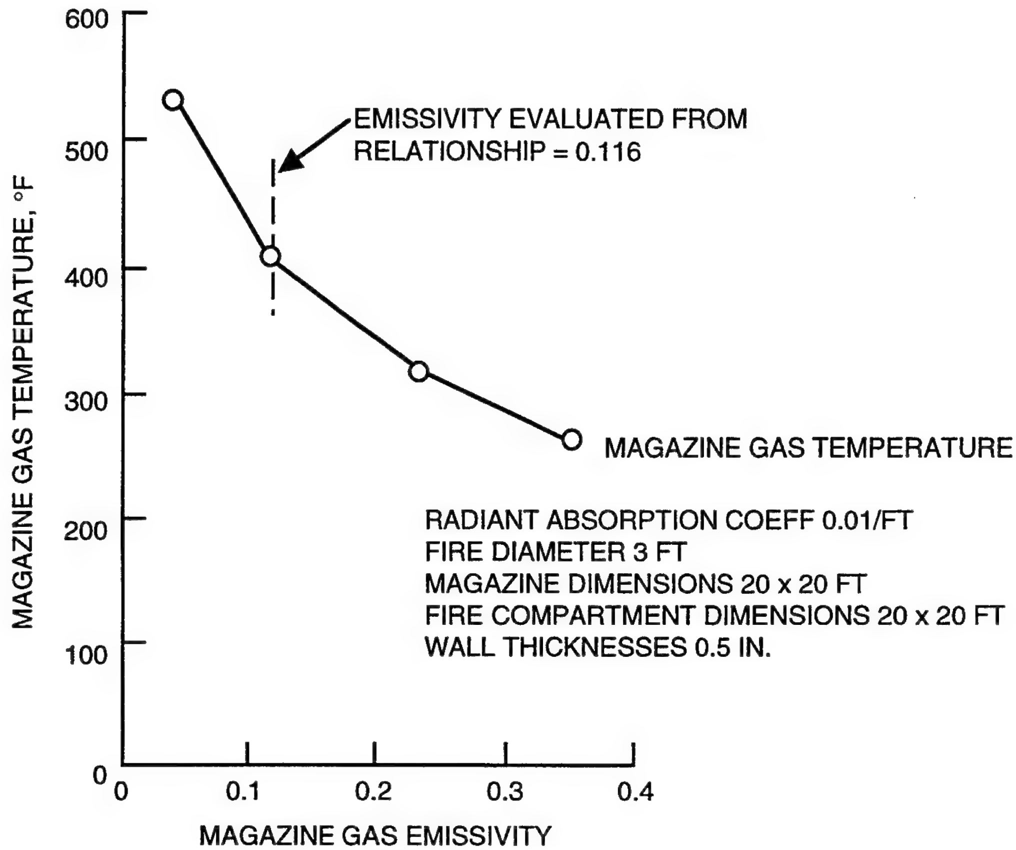


FIGURE 13. The Effect of the Ratio of Absorption Coefficient to Emissivity.

2.8 THE EFFECT OF ORDNANCE LOCATION

Ordnance heating evaluation requires radiation view factors between the bulkhead and ordnance surface points. Appropriate view factors have been incorporated into the program MFIRE for any ordnance position in the magazine, but the view factors are restricted at this time to cylindrical ordnance configuration. Other configurations are common; for example, some ordnance is stored within rectangular crates. The view factor capability of MFIRE should be expanded.

Results of the view factor evaluation are shown in Figures 14 and 15. Heat input along the surface of the ordnance for various bulkhead temperatures is given in Figure 14, and the effect of ordnance height above the deck is given in Figure 15.

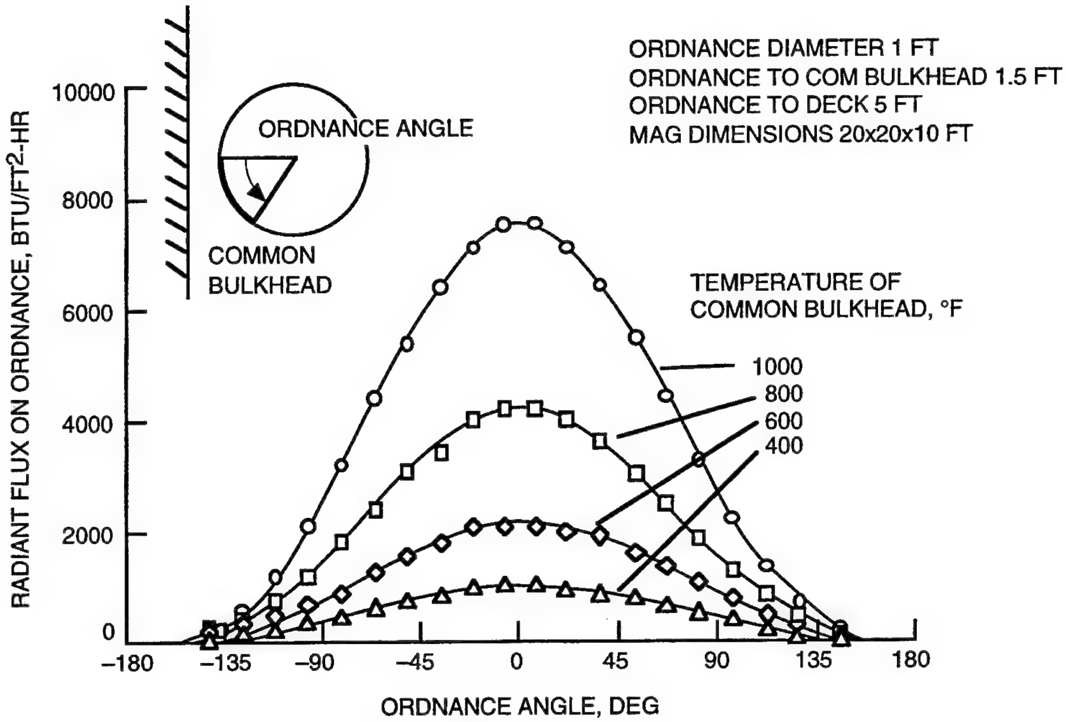


FIGURE 14. Ordnance Exposure Level Versus Bulkhead Temperature.

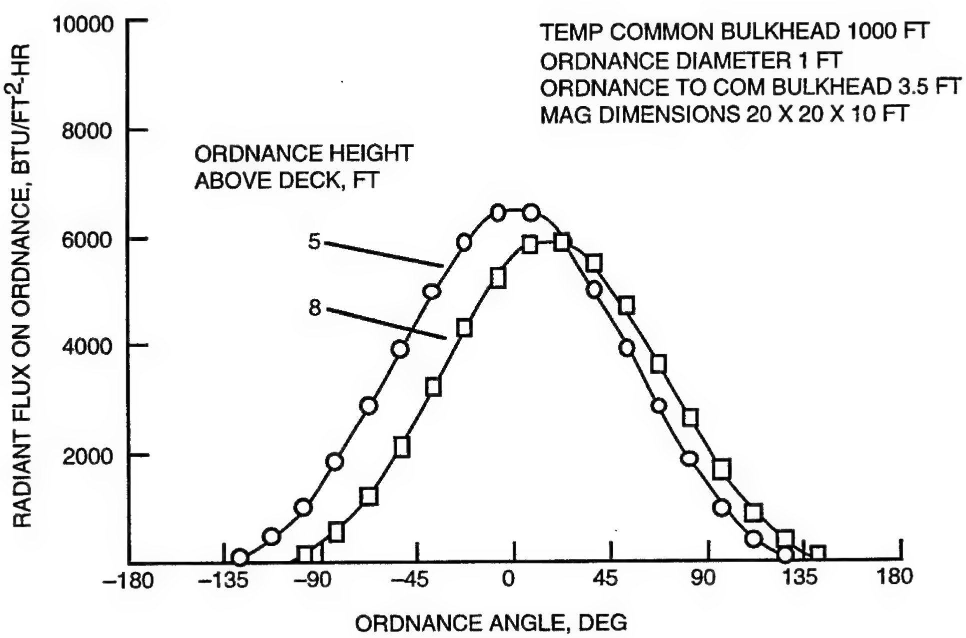


FIGURE 15. Ordnance Exposure Level Versus Ordnance Height Above Deck.

SECTION 3

SUMMARY

The analysis of ordnance heating has shown that ordnance in magazines can experience a broad range of heating levels, and that there are a large number of <u>sets</u> of conditions that result in similar ordnance exposure.

The specific findings for the common bulkhead and magazine gas are:

- 1. The equilibrium temperature reached by the common bulkhead is governed primarily by the fire size and fire compartment size (surface area). Bulkhead temperature is not sensitive to properties of the compartments that surround the fire compartment (the magazine and adjacent compartments).

- 2. The equilibrium temperature of the magazine gas is sensitive to a number of factors, including fire size and the dimensions of both the fire compartment and magazine.

- 3. The temperatures of the common bulkhead and magazine gas are not sensitive to the dimensions of the adjacent compartments. The location of the magazine/fire compartment pair is not particularly important.

- 4. Neither the common bulkhead nor the magazine gas is sensitive to the soot concentration for a constant ratio of the radiant absorption coefficient to emissivity. The bulkhead temperature is not sensitive to the ratio, but the magazine gas temperature is highly sensitive to the ratio.

- 5. The wall thicknesses of the compartment system do not affect the equilibrium temperatures, but affect the temperature at a given time.

- 6. The time response of the common bulkhead and magazine gas temperatures is affected significantly by the fire size and fire compartment dimensions. The magazine dimensions do not significantly affect the response time of the magazine gas or common bulkhead.

RECOMMENDATIONS

There are two important technical issues that need to be resolved to more clearly bracket ordnance heating and to raise the prediction confidence of the analysis. These are (1), to determine the fire sizes that are likely to occur, and (2), to determine the ratio of the radiation absorption coefficient to emissivity associated with the magazine soot cloud.

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4. D. A. Kourtides and J. A. Parker. "Assessment of Relative Flammability and Thermochemical Properties of Some Thermoplastic Materials," *Polymer Engineering and Science*, Vol. 18, No. 11 (August 1978).

5. D. A. Kourtides, D.A. "Graphite Composites with Advanced Resin Matrices," in *Proceedings of AIAA 21st Structures, Structural Dynamics and Materials Conference, May 12-14, 1980.* Seattle, Wash.

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APPENDIX A. COMPUTER PROGRAM LISTING OF MFIRE

```
C THIS PROGRAM, MFIRE, CALCULATES TEMPERATURE WITH TIME FOR THE
C   WALLS OF AND GASES WITHIN A SYSTEM OF STEEL WALL COMPARTMENTS,
C   WHERE THERE IS A FIRE IN ONE OF THE COMPARTMENTS. COMPARTMENT
C   SIZES, FIRE SIZE AND SOOT CONCENTRATION CAN BE VARIED.
C
C INPUT PARAMETERS ARE INSERTED DIRECTLY IN THE PROGRAM BELOW.
C   PROGRAM OUTPUT IS CONTAINED IN A FILE NAMED 'MFIREOUT'.
C
C THE PROGRAM PROVIDES ESTIMATES NECESSARY TO EVALUATE THE HEAT
C   INPUT TO ORDNANCE THAT ARE CONTAINED IN A MAGAZINE, WHERE THE
C   MAGAZINE IS JOINED BY A COMMON BULKHEAD TO THE FIRE COMPARTMENT.
C
C THE PROGRAM ALSO DETERMINES RADIATION VIEW FACTORS FOR RADIANT
C   TRANSFER FROM THE WALLS TO ORDNANCE LOCATED IN A COMPARTMENT
C   (MAGAZINE) ADJACENT TO THE FIRE COMPARTMENT.
C
      OPEN(7,FILE='MFIREOUT')
      DIMENSION D(6,6),F(6,6), A(6,6),T(6,6),BVF(72),FENG(72),FLU(72)
      REAL MAGWI, MAGLE, MAGHE, MAGAR, MAGV
C INPUT PARAMETERS
C
C FIRE DIAMETER IN FEET
      DFIRE=4.0
C FUEL COMBUSTION ENERGY IN BTU/LB
      FUELEN=20000.0
C FRACTION OF COMBUSTION ENERGY LOST THRU EXIT PORT BEFORE STIRRING
      FR=0.0
C FIRE COMPARTMENT WIDTH, LENGTH & HEIGHT IN FEET
      COMPWI=20.0
      COMPLE=30.0
      COMPHE=10.0
C MAGAZINE WIDTH, LENGTH & HEIGHT IN FEET
      MAGWI=20.0
      MAGLE=30.0
      MAGHE=10.0
C NEEDED DIMENSIONS OF ADJACENT COMPARTMENTS 2,3,4,5 & 6 IN FEET
      COMPW2=15.0
      COMPL3=15.0
      COMPW4=15.0
      COMPH5=10.0
      COMPH6=10.0
C WALL THICKNESSES FOR FIRE COMPARTMENT IN INCHES
      WT1I=0.50
      WT2I=0.50
      WT3I=0.50
      WT4I=0.50
      WT5I=0.50
      WT6I=0.50
```

```
C WALL THICKNESSES OF MAGAZINE IN INCHES
      WTM2I=0.50
      WTM3I=0.50
      WTM4I=0.50
      WTM5I=0.50
      WTM6I=0.50
C WALL THICKNESSES OF ADJACENT COMPARTMENTS 2,3,4,5 & 6 IN INCHES
      WTA2I=0.50
      WTA3I=0.50
      WTA4I=0.50
      WTA5I=0.50
      WTA6I=0.50
C DENSITIES OF STEEL, AIR & COMBUSTION GAS IN LB/FT^3
      DST=490.1
      DAIR=0.0805
      DCO=0.0900
C SPECIFIC HEATS OF STEEL, AIR & COMBUSTION GAS IN BTU/LB-F
      CST=0.118
      CAIR=0.24
      CCOGAS=0.335
C RADIATION CONSTANT IN BTU/FT^2-HR-R^4
      SIGMA=0.171E-08
C INPUT VALUE OF MAGAZINE GAS EMISSIVITY
      EMMGAS=0.23
C NR IS 1 IF USE BUILT IN RULE BETWEEN MAG EMISSIVITY & ABS COEFF
      NR=1
C RADIATION ABSORPTION COEFFICIENT OF MAGAZINE GAS IN 1/FT
      AM=0.01
C INITIAL SYSTEM TEMP IN DEG F
      TINIT=70.0
C HEAT TRANSFER COEFFICIENTS INSIDE FIRE COMPARTMENT (HC), INSIDE
C   MAGAZINE & ADJACENT COMPARTMENTS (HCMAG), & OUTSIDE OF ADJACENT
C   COMPARTMENTS (HCO), IN BTU/FT^2-HR-F
      HC=0.48
      HCMAG=0.36
      HCO=0.36
C INPUT RELATED TO ORDNANCE
C   ORDNANCE DIAMETER IN FEET
      DORD=1.0
C   DISTANCE FROM ORDNANCE AXIS TO DECK IN FEET
      HORD=5.0
C   DISTANCE FROM ORDNANCE AXIS TO COMMON BULKHEAD IN FEET
      ZORD=1.0
C   DISTANCE FROM SELECTED POINT ALONG ORDNANCE AXIS TO EITHER SIDE
C   BULKHEAD OF MAGAZINE IN FEET
      XORD=10.0
C    INTEGER NUMBER OF COMPUTATIONAL BULKHEAD ELEMENTS BETWEEN
C   ORDNANCE AND DECK OR OVERHEAD, WHICHEVER IS LARGER
      NY=16
C   INTEGER NUMBER OF COMPUTATIONAL BULKHEAD ELEMENTS BETWEEN
C   SELECTED ORDNANCE POINT AD SIDE BULKHEAD
      NX=10
C   ORDNANCE SURFACE COMPUTATIONAL ANGULAR INTERVAL IN DEGREES
      DA=15.0
```

```
C  N2 IS 1 IF WANT ENERGY FROM EACH Y STRIP PRINTED, OTHERWISE 0
      N2=0
C
C  END OF INPUT
C
C  FORMATTING
 11   FORMAT(10X,F9.2,/)
 13   FORMAT(6X,'FIRE DIAMETER (FT)')
 14   FORMAT(6X,'FIRE COMP DIMENSIONS (FT)     MAG DIMENSIONS (FT)')
 15   FORMAT(10X,'LE       WI       HT                 LE       WI       HT')
 16   FORMAT(7X,3F6.1,7X,3F6.1,/)
 17   FORMAT(6X,E9.3,/)
 18   FORMAT(6X,'RADIATION ABSORPTION COEFF OF MAG GAS, 1/FT')
 19   FORMAT(6X,'FUEL COMBUSTION ENERGY (BTU/LB)')
 20   FORMAT(8X,F8.1,19X,F6.3,/)
 21   FORMAT(7X,'COMPS, & OUTSIDE MAG & ADJ COMPS (BTU/FT^2-HR-F)')
 22   FORMAT(13X,'COMP              MAG              OUTSIDE')
 24   FORMAT(6X,'INPUT EMISSIVITY OF MAGAZINE GAS')
 25   FORMAT(6X,'HEAT TRANSFER COEFFS IN FIRE COMP, IN MAG & ADJ')
 26   FORMAT(12X,F5.2,8X,F5.2,8X,F5.2,//)
 27   FORMAT(6X,E9.3,//)
 49   FORMAT(6X,'FRACTION OF ENERGY LOST BEFORE STIRRING')
 50   FORMAT(8X,F4.2,/)
 51   FORMAT(6X,'DENSITIES (LB/FT^3)')
 52   FORMAT(7X,'STEEL     AIR   COMB GAS')
 53   FORMAT(6X,F6.1,F8.4,F8.4,/)
 54   FORMAT(6X,'SPECIFIC HEATS (BTU/LB-F)')
 55   FORMAT(6X,F6.3,F7.3,F8.3,/)
 56   FORMAT(6X,'WALL THICKNESSES (INCHES)')
 59     FORMAT(7X,'FIRE COMP SURFACES 1,2,3,4,5 & 6')
 60     FORMAT(6X,6F7.3)
 61     FORMAT(13X,5F7.3)
 62     FORMAT(7X,'MAGAZINE SURFACES 2,3,4,5 & 6')
 63     FORMAT(13X,5F7.3,/)
 64     FORMAT(7X,'ADJACENT COMPARTMENTS 2,3,4,5 & 6')
 65     FORMAT(6X,'DIMENSIONS FOR ADJACENT COMPARTMENTS 2,3,4,5 & 6')
 66     FORMAT(8X,'COMPW2  COMPL3  COMPW4  COMPH5  COMPH6')
 67     FORMAT(5X,5F8.2,/)
 68   FORMAT(6X,'RADIANT ENERGY ABSORBED BY MAGAZINE GAS',/)
 69   FORMAT(8X,'FROM          TO               DISTANCE        FRACTION')
 70   FORMAT(6X,'WALL NO.    WALL NO.            FEET              ABSORBED',/)
 71   FORMAT(8X,I2,7X,I2,9X,F6.2,5X,E11.5)
 72   FORMAT(/,6X,'MAGAZINE VIEW FACTORS')
 73   FORMAT(8X,'FROM          TO                    VIEW')
 74   FORMAT(6X,'WALL NO.   WALL NO.            FACTOR')
 75   FORMAT(8X,I2,7X,I2,8X,E11.5)
 76   FORMAT(///,3X,'GAS & WALL TEMPS WITH TIME',/)
 77   FORMAT(12X,'TEMP-F    TEMP-F    TEMP-F    TEMP-F    TEMP-F')
 78   FORMAT(3X,'TIME')
 79   FORMAT(4X,'HR')
 80   FORMAT(10X,'FC GAS    MAG GAS   COM WALL')
```

```
 81   FORMAT(11X,'2',9X,'3',9X,'4',9X,'5',9X,'6    # FC WALL')
 82   FORMAT(12X,'2',9X,'3',9X,'4',9X,'5',9X,'6   # MAG WALL')
 83   FORMAT(13X,'2',9X,'3',9X,'4',9X,'5',9X,'6  # ADJ C GAS')
 84   FORMAT(14X,'2',9X,'3',9X,'4',9X,'5',9X,'6 # ADJ C WALL',/)
 85   FORMAT(2X,F5.3,3F10.2)
 86   FORMAT(8X,5F10.2)
 87   FORMAT(9X,5F10.2)
 88   FORMAT(10X,5F10.2)
 89   FORMAT(11X,5F10.2,/)
 90   FORMAT(6X,F14.3,2E14.4)
 91   FORMAT(3X,F12.1,3E14.4,/)
 92   FORMAT(6X,'ORDNANCE DIAMETER (FT)')
 93   FORMAT(6X,F6.3,/)
 94   FORMAT(6X,'DISTANCE FROM ORDNANCE AXIS TO DECK (FT)')
 95   FORMAT(6X,'DISTANCE FROM ORDNANCE AXIS TO COMMON BULKHEAD(FT)')
 96   FORMAT(6X,'DISTANCE FROM SELECTED POINT OF INTEREST ALONG')
 97   FORMAT(6X,'ORDNANCE AXIS TO EITHER SIDE BULKHEAD OF MAG (FT)')
 99   FORMAT(6X,'ORDNANCE SEGMENT ANGLE (DEGREES)')
 100  FORMAT(6X,F7.3,/)
 101  FORMAT(6X,'NUMBER OF HORIZONTAL BULKHEAD SEGMENTS')
 102  FORMAT(6X,I3,/)
 103  FORMAT(6X,'NUMBER OF VERTICAL BULKHEAD SEGMENTS')
 104  FORMAT(7X,4E11.3)
 105  FORMAT(/,12X,F6.1)
 111  FORMAT(/,13X,'THETA')
 112  FORMAT(9X,'FLUX(400F) FLUX(600F) FLUX(800F) FLUX(1000F)')
 113  FORMAT(9X,'ENG(400F)  ENG(600F)  ENG(800F)  ENG(1000F)')
 115  FORMAT(/,5X,'RADIATION FROM COMMON BULKHEAD ON ORDNANCE')
 116  FORMAT(/,6X,'THETA (ORDNANCE ANGLE)=ANGLE BETWEEN LINE')
 117  FORMAT(6X,'PERPENDICULAR TO COMMON BULKHEAD THROUGH')
 118  FORMAT(6X,'ORDNANCE AXIS AND LINE FROM ORDNANCE AXIS')
 119  FORMAT(6X,'TO ORDNANCE SURFACE ELEMENT',/)
 120  FORMAT(6X,'FLUX=INCIDENT FLUX (BTU/FT^2-HR) ON ORDNANCE')
 121  FORMAT(6X,'SURFACE AT ORDNANCE ANGLE THETA FOR INDICATED')
 122  FORMAT(6X,'TEMPERATURE OF COMMON BULKHEAD',/)
 123  FORMAT(6X,'ENG=INCIDENT ENERGY PER UNIT TIME (BTU/HOUR)')
 124  FORMAT(6X,'ON ORDNANCE SURFACE ELEMENT AT THETA FOR')
 125  FORMAT(6X,'INDICATED TEMP OF COMMON BULKHEAD',/)
 126  FORMAT(/,'CALCULATED EMISSIVITY OF MAGAZINE GAS')
C
C
C FUEL SURFACE AREA
      AFIRE=0.785*DFIRE**2.0
C RATE FUEL MASS ENTERS FIRE
      FUELMS=46.06*AFIRE
C RATE FIRE GENERATES ENERGY
      FRR=1.0-FR
      QFIRE=FUELMS*FUELEN*FRR
C COMPARTMENT & MAGAZINE SURFACE AREAS
      COMPAR=2.0*((COMPLE*COMPHE)+(COMPWI*COMPHE)+(COMPWI*COMPLE))
      MAGAR=2.0*((MAGLE*MAGHE)+(MAGWI*MAGHE)+(MAGWI*MAGLE))
```

```
C  SURFACE AREAS OF FIRE COMPARTMENT WALLS, OVERHEAD & DECK
      AC1=COMPWI*COMPHE
      AC2=COMPLE*COMPHE
      AC3=AC1
      AC4=AC2
      AC5=COMPLE*COMPWI
      AC6=AC5
C  SURFACE AREAS OF MAGAZINE WALLS, OVERHEAD & DECK
      AM1=MAGWI*MAGHE
      AM2=MAGLE*MAGHE
      AM3=MAGWI*MAGHE
      AM4=AM2
      AM5=MAGLE*MAGWI
      AM6=AM5
C  SURFACE AREAS OF ADJACENT COMPARTMENTS (5 SURFACES EACH)
      AAC2=2.0*(COMPHE*COMPW2+COMPLE*COMPW2)+COMPLE*COMPHE
      AAC3=2.0*(COMPHE*COMPL3+COMPWI*COMPL3)+COMPWI*COMPHE
      AAC4=2.0*(COMPHE*COMPW4+COMPLE*COMPW4)+COMPLE*COMPHE
      AAC5=2.0*(COMPWI*COMPH5+COMPLE*COMPH5)+COMPLE*COMPWI
      AAC6=2.0*(COMPWI*COMPH6+COMPLE*COMPH6)+COMPLE*COMPWI
C  COMPARTMENT & MAGAZINE VOLUMES
      COMPV=COMPLE*COMPWI*COMPHE
      MAGV=MAGLE*MAGWI*MAGHE
      COMP2V=COMPLE*COMPHE*COMPW2
      COMP3V=COMPWI*COMPHE*COMPL3
      COMP4V=COMPLE*COMPHE*COMPW4
      COMP5V=COMPLE*COMPWI*COMPH5
      COMP6V=COMPLE*COMPWI*COMPH6
C  WALL THICKNESSES CONVERTED TO FEET
      WT1=WT1I/12.0
      WT2=WT2I/12.0
      WT3=WT3I/12.0
      WT4=WT4I/12.0
      WT5=WT5I/12.0
      WT6=WT6I/12.0
      WTM2=WTM2I/12.0
      WTM3=WTM3I/12.0
      WTM4=WTM4I/12.0
      WTM5=WTM5I/12.0
      WTM6=WTM6I/12.0
      WTA2=WTA2I/12.0
      WTA3=WTA3I/12.0
      WTA4=WTA4I/12.0
      WTA5=WTA5I/12.0
      WTA6=WTA6I/12.0
C
C  DISTANCES BETWEEN MAGAZINE WALLS
C
      D(1,4)=((MAGWI/2.0)**2.0+(MAGLE/2.0)**2.0)**0.5
      D(1,2)=D(1,4)
      D(1,3)=MAGLE
      D(1,5)=((MAGLE/2.0)**2.0+(MAGHE/2.0)**2.0)**0.5
      D(1,6)=D(1,5)
```

```
C
      D(2,1)=D(1,4)
      D(2,3)=D(1,4)
      D(2,4)=MAGWI
      D(2,5)=((MAGHE/2.0)**2.0+(MAGWI/2.0)**2.0)**0.5
      D(2,6)=D(2,5)
C
      D(4,1)=D(1,4)
      D(4,3)=D(1,4)
      D(4,2)=D(2,4)
      D(4,5)=D(2,5)
      D(4,6)=D(2,6)
C
      D(3,1)=D(1,3)
      D(3,2)=D(1,4)
      D(3,4)=D(1,4)
      D(3,5)=D(1,5)
      D(3,6)=D(1,5)
C
      D(5,1)=((MAGLE/2.0)**2.0+(MAGHE/2.0)**2.0)**0.5
      D(5,3)=D(5,1)
      D(5,2)=((MAGWI/2.0)**2.0+(MAGHE/2.0)**2.0)**0.5
      D(5,4)=D(5,2)
      D(5,6)=MAGHE
C
      D(6,1)=D(5,1)
      D(6,3)=D(5,1)
      D(6,2)=D(5,2)
      D(6,4)=D(5,2)
      D(6,5)=D(5,6)
C
      WRITE(7,13)
      WRITE(7,11)DFIRE
      WRITE(7,14)
      WRITE(7,15)
      WRITE(7,16)COMPLE,COMPWI,COMPHE,MAGLE,MAGWI,MAGHE
      WRITE(7,65)
      WRITE(7,66)
      WRITE(7,67)COMPW2,COMPL3,COMPW4,COMPH5,COMPH6
      WRITE(7,19)
      WRITE(7,20)FUELEN
      WRITE(7,49)
      WRITE(7,50)FR
      WRITE(7,51)
      WRITE(7,52)
      WRITE(7,53)DST,DAIR,DCO
      WRITE(7,54)
      WRITE(7,52)
      WRITE(7,55)CST,CAIR,CCOGAS
      WRITE(7,56)
      WRITE(7,59)
      WRITE(7,60)WT1I,WT2I,WT3I,WT4I,WT5I,WT6I
      WRITE(7,62)
      WRITE(7,61)WTM2I,WTM3I,WTM4I,WTM5I,WTM6I
```

```
      WRITE(7,64)
      WRITE(7,63)WTA2I,WTA3I,WTA4I,WTA5I,WTA6I
      WRITE(7,25)
      WRITE(7,21)
      WRITE(7,22)
      WRITE(7,26)HC,HCMAG,HCO
      WRITE(7,24)
      WRITE(7,17)EMMGAS
      WRITE(7,18)
      WRITE(7,27)AM
      WRITE(7,92)
      WRITE(7,93)DORD
      WRITE(7,94)
      WRITE(7,93)HORD
      WRITE(7,95)
      WRITE(7,93)ZORD
      WRITE(7,96)
      WRITE(7,97)
      WRITE(7,93)XORD
      WRITE(7,99)
      WRITE(7,100)DA
      WRITE(7,101)
      WRITE(7,102)NX
      WRITE(7,103)
      WRITE(7,102)NY
C
C RADIANT ENERGY ABSORBED BY MAGAZINE GAS
C
      I=1
      J=2
      WRITE(7,68)
      WRITE(7,69)
      WRITE(7,70)
 212  AD=D(I,J)*AM
      T(I,J)=1.0/EXP(AD)
      A(I,J)=1.0-T(I,J)
      WRITE(7,71)I,J,D(I,J),A(I,J)
      J=J+1
      IF(J .EQ. I)J=J+1
      IF(J .GT. 6)GO TO 210
      GO TO 212
 210  I=I+1
      J=1
      IF(I .GT. 6)GO TO 215
      GO TO 212
C
C MAGAZINE WALL TO WALL VIEW FACTORS
C
      215 I=1
      J=2
      X=MAGLE/MAGHE
      Y=MAGWI/MAGHE
```

```
220  X2=X**2.0
     Y2=Y**2.0
     X1=1.0+X2
     Y1=1.0+Y2
     Z=X2+Y2
     Z1=1.0+Z
     A1=X1*Y1/Z1
     GT1=0.25*LOG(A1)
     A2=Y2*Z1/(Z*Y1)
     GT2=0.25*Y2*LOG(A2)
     A3=X2*Z1/(Z*X1)
     GT3=0.25*X2*LOG(A3)
     GT4=Y*ATAN(1.0/Y)
     GT5=X*ATAN(1.0/X)
     A4=Z**0.5
     GT6=A4*ATAN(1.0/A4)
     F(I,J)=(1.0/(3.1416*Y))*(GT1+GT2+GT3+GT4+GT5-GT6)
     IF(J .EQ. 5)GO TO 222
     IF((I .EQ. 5) .AND. (J .EQ. 2))GO TO 226
     J=5
     IF(I .EQ. 2)GO TO 224
     IF(I .EQ. 5)GO TO 228
     X=MAGLE/MAGWI
     Y=MAGHE/MAGWI
     GO TO 220
224  X=MAGWI/MAGLE
     Y=MAGHE/MAGLE
     GO TO 220
228  J=2
     X=MAGHE/MAGLE
     Y=MAGWI/MAGLE
     GO TO 220
222  IF(I .EQ. 2)GO TO 230
     J=3
     IF(I .EQ. 5)GO TO 226
     X=MAGWI/MAGLE
     Y=MAGHE/MAGLE
     GO TO 232
230  J=4
     X=MAGHE/MAGWI
     Y=MAGLE/MAGWI
     GO TO 232
226  J=6
     X=MAGLE/MAGHE
     Y=MAGWI/MAGHE
232  X2=X**2.0
     Y2=Y**2.0
     X1=1.0+X2
     Y1=1.0+Y2
     B1=((X1*Y1)/(1.0+X2+Y2))**0.5
     HT1=LOG(B1)
     B2=Y/((X1)**0.5)
     HT2=Y*(X1**0.5)*ATAN(B2)
     B3=X/((Y1)**0.5)
```

```
      HT3=X*(Y1**0.5)*ATAN(B3)
      HT4=Y*ATAN(Y)
      HT5=X*ATAN(X)
      F(I,J)=(2.0/(3.1416*X*Y))*(HT1+HT2+HT3-HT4-HT5)
      IF(J .EQ. 6)GO TO 234
      IF(J .EQ. 4)GO TO 236
      I=2
      J=1
      X=MAGWI/MAGHE
      Y=MAGLE/MAGHE
      GO TO 220
 236  I=5
      J=1
      X=MAGHE/MAGWI
      Y=MAGLE/MAGWI
      GO TO 220
 234  F(1,4)=F(1,2)
      F(3,4)=F(1,2)
      F(3,2)=F(1,2)
      F(1,6)=F(1,5)
      F(3,6)=F(1,5)
      F(3,5)=F(1,5)
      F(3,1)=F(1,3)
      F(2,3)=F(2,1)
      F(4,3)=F(2,1)
      F(4,1)=F(2,1)
      F(2,6)=F(2,5)
      F(4,6)=F(2,5)
      F(4,5)=F(2,5)
      F(4,2)=F(2,4)
      F(5,3)=F(5,1)
      F(6,1)=F(5,1)
      F(5,4)=F(5,2)
      F(6,2)=F(5,2)
      F(6,3)=F(5,1)
      F(6,4)=F(5,2)
      F(6,5)=F(5,6)
C
      WRITE(7,72)
      WRITE(7,73)
      WRITE(7,74)
      I=1
      J=2
 238  WRITE(7,75)I,J,F(I,J)
      J=J+1
      IF(J .EQ. I)J=J+1
      IF(J .GT. 6)GO TO 240
      GO TO 238
 240  J=1
      I=I+1
      IF(I .GT. 6)GO TO 241
      GO TO 238
```

```
C
C
C  RADIANT ENERGY DISTRIBUTION ALONG ORDNANCE SURFACE
C   (VIEW FACTORS FOR EACH POSITION ON ORDNANCE SURFACE)
C
 241  WRITE(7,115)
      WRITE(7,116)
      WRITE(7,117)
      WRITE(7,118)
      WRITE(7,119)
      WRITE(7,120)
      WRITE(7,121)
      WRITE(7,122)
      WRITE(7,123)
      WRITE(7,124)
      WRITE(7,125)
      WRITE(7,111)
      WRITE(7,112)
      WRITE(7,113)
      ZB=ZORD
      RB=DORD/2.0
      FLO1=MAGHE-HORD
      IF(FLO1 .GT. HORD)GO TO 301
      YB=HORD
      GO TO 302
 301  YB=FLO1
 302  FLO2=MAGWI-XORD
      IF(FLO2 .GT. XORD)GO TO 303
      XB=XORD
      GO TO 304
 303  XB=FLO2
 304  ANX=NX
      ANY=NY
      NTH=0
      NCOUNT=0
      DXI=XB/ANX
      DYI=YB/ANY
      DAR=DA*0.017453
      TH=DAR/2.0
      CYD=-(MAGHE-YB)
      VFS=0.0
      VFSY=0.0
      XI=XB-DXI/2.0
      YI=YB-DYI/2.0
 315  YJ=RB*SIN(TH)
      ZJ=ZB-RB*COS(TH)
 317  IF(TH .LT. 0.0)GO TO 322
      IF(TH .GT. 1.5707963)GO TO 318
      RBS=RB*SIN(TH)
      IF(YI .GT. RBS)GO TO 320
      TSA=(RB*SIN(TH)-YI)/(ZB-RB*COS(TH))
      SA=ATAN(TSA)
      SU5=TH+SA
```

```
      IF(SU5 .GT. 1.5707963)GO TO 339
      GO TO 320
318   NCOUNT=NCOUNT+1
      IF(YI .LT. RB)GO TO 339
      THM=TH-1.5707963
      TAG=(ZB-RB*SIN(THM))/(YI-RB*COS(THM))
      GAG=ATAN(TAG)
      SU6=TH+GAG
      IF((NCOUNT .EQ. 1) .AND. (SU6 .GT. 3.14  ))GO TO 345
      IF(SU6 .GT. 3.00  )GO TO 339
      GO TO 320
322   THA=ABS(TH)
      IF(THA .GT. 1.570796)GO TO 325
323   TGAM=(ZB-RB*COS(THA))/(YI+RB*SIN(THA))
      GAM=ATAN(TGAM)
      IF(THA .LT. GAM)GO TO 320
      YI=YI-DYI
      IF(YI .GT. 0.0)GO TO 323
      AYI=ABS(YI)
      RBS=RB*SIN(THA)
324   IF(AYI .GT. RBS)GO TO 320
      GO TO 323
325   YI=-DYI/2.0
326   AYI=ABS(YI)
      IF(AYI .GT. RB)GO TO 327
      YI=YI-DYI
      GO TO 326
327   CAN=THA-1.570796
328   IF(YI .LT. CYD)GO TO 350
      AYI=ABS(YI)
      TAB=(ZB+RB*SIN(CAN))/(AYI-RB*COS(CAN))
      BAG=ATAN(TAB)
      CRIT=BAG+CAN
      IF(CRIT .LT. 1.570796)GO TO 320
      YI=YI-DYI
      GO TO 328
320   R=((XI**2.0)+((YI-YJ)**2.0)+(ZJ**2.0))**0.5
      CBI=ZJ/R
      CBJ=(((ZJ/COS(TH))**2.0)+(R**2.0)-((XI**2.0)+((YI-ZB*TAN(TH))
     1**2.0)))/(2.0*(ZJ/COS(TH))*R)
      VF=CBI*CBJ*DAR*RB/(3.141593*(R**2.0))
      IF(VF .LT. 0.0)GO TO 335
      VFS=VFS+VF
      REM=MAGWI-XB-DXI/2.0
      IF(XI .GT. REM)GO TO 330
      VFS=VFS+VF
330   XI=XI-DXI
      IF(XI .LT. 0.0)GO TO 335
      GO TO 320
335   VFSY=VFSY+VFS
      IF(N2 .EQ. 0)GO TO 337
      WRITE(7,90)YI,VFS,VFSY
```

```
 337  YI=YI-DYI
      XI=XB-DXI/2.0
      VFS=0.0
      IF((YI .GT. CYD) .AND. (TH .LT. 0.0))GO TO 320
      IF(YI .GT. CYD)GO TO 317
 339  NTH=NTH+1
      IF(NTH .GT. 100)GO TO 110
      BVF(NTH)=VFSY
      THD=TH/0.017453
      FENG(NTH)=BVF(NTH)*DXI*DYI
      FLU(NTH)=FENG(NTH)/(DAR*RB)
      WRITE(7,105)THD
      ENG4=FENG(NTH)*935.4
      ENG6=FENG(NTH)*2158.8
      ENG8=FENG(NTH)*4310.0
      ENG10=FENG(NTH)*7769.8
      FLUX4=FLU(NTH)*935.4
      FLUX6=FLU(NTH)*2158.8
      FLUX8=FLU(NTH)*4310.0
      FLUX10=FLU(NTH)*7769.8
      WRITE(7,104)FLUX4,FLUX6,FLUX8,FLUX10
      WRITE(7,104)ENG4,ENG6,ENG8,ENG10
      NCOUNT=0
      VFSY=0.0
      VFS=0.0
      XI=XB-DXI/2.0
      YI=YB-DYI/2.0
      IF(TH .LT. 0.0)GO TO 340
      TH=TH+DAR
      GO TO 315
 340  TH=TH-DAR
      GO TO 315
 345  TH=-DAR/2.0
      XI=XB-DXI/2.0
      YI=YB-DYI/2.0
      VFS=0.0
      VFSY=0.0
      GO TO 315
C
C
C  EVALUATION OF EMISSIVITY OF MAGAZINE GAS
C
 350  IF(NR .EQ. 0)GO TO 242
      IF(AM .LE. 1.00)GO TO 243
      EMMGAS=0.99
      GO TO 280
 243  IF(AM .LT. 0.5)GO TO 244
      IF(MAGLE .GE. 10.0)GO TO 271
      EMMGAS=0.097*(0.70103*AM+0.29896)*MAGLE
      GO TO 280
 271  IF(MAGLE .LT. 40.0)GO TO 272
      EMMGAS=0.995
      GO TO 280
```

```
272  FM=-22.666*AM+23.666
     GM=0.944444*AM+0.055556
     EMMGAS=FM*0.001*MAGLE+(GM*0.96)
     GO TO 280
244  IF(AM .LT. 0.1)GO TO 245
     IF(MAGLE .GT. 10.0)GO TO 273
     FB=1.11112*AM+0.44444
     EMMGAS=FB*0.063*MAGLE
     GO TO 280
273  FZ=0.22827*AM+0.885865
     GZ=1.326*AM+0.337
     EMMGAS=0.012333*FZ*MAGLE+(GZ*0.506667)
     GO TO 280
245  IF(AM .LT. 0.05)GO TO 246
     IF(MAGLE .GT. 10.0)GO TO 274
     FW=8.57143*AM+0.142857
     EMMGAS=0.035*FW*MAGLE
     GO TO 280
274  FY=6.6154*AM+0.33846
     GY=9.4928*AM+0.05072
     EMMGAS=0.0112069*FY*MAGLE+(GY*0.237931)
     GO TO 280
246  IF(AM .LT. 0.01)GO TO 247
     IF(MAGLE .GT. 10.0)GO TO 275
     FK=14.375*AM+0.28125
     EMMGAS=0.02*FK*MAGLE
     GO TO 280
275  FM=14.3333*AM+0.283333
     GM=14.5*AM+0.275
     EMMGAS=0.0075*FM*MAGLE+(GM*0.125)
     GO TO 280
247  IF(AM .LT. 0.005)GO TO 248
     IF(MAGLE .GT. 10.0)GO TO 276
     FB=152.942*AM-0.52942
     EMMGAS=0.0085*FB*MAGLE
     GO TO 280
276  FL=76.923*AM+0.23077
     GL=200.0*AM-1.0
     EMMGAS=0.00325*FL*MAGLE+(GL*0.0525)
     GO TO 280
248  IF(AM .LT. 0.001)GO TO 249
     FH=175.0*AM+0.125
     EMMGAS=0.002*FH*MAGLE
     GO TO 280
249  FJ=740.7444*AM+0.259255
     EMMGAS=0.0006*FJ
280  IF(EMMGAS .LT. 1.000)GO TO 242
     EMMGAS=0.995
242  WRITE(7,126)
     WRITE(7,17)EMMGAS
```

```
C
C INITIAL CONDITIONS
C
      T4IN=SIGMA*(TINIT+460.0)**4.0
      TIM=0.0
      TI=0.0002778
      NTI=0
      DK=131.32*(DFIRE**2.0)
      TG=75.0
      TMG=71.0
      TW1=72.0
      TW2=72.0
      TW3=72.0
      TW4=72.0
      TW5=72.0
      TW6=72.0
      TMW2=70.5
      TMW3=70.5
      TMW4=70.5
      TMW5=70.5
      TMW6=70.5
      TG2=71.0
      TG3=71.0
      TG4=71.0
      TG5=71.0
      TG6=71.0
      TAW2=70.5
      TAW3=70.5
      TAW4=70.5
      TAW5=70.5
      TAW6=70.5
C
C CONSTANTS IN ENERGY EQUATIONS
C
      R1=F(1,2)*A(1,2)+F(1,3)*A(1,3)+F(1,4)*A(1,4)+F(1,5)*A(1,5)
     1+F(1,6)*A(1,6)
      R2=F(2,1)*A(2,1)+F(2,3)*A(2,3)+F(2,4)*A(2,4)+F(2,5)*A(2,5)
     1+F(2,6)*A(2,6)
      R3=F(3,1)*A(3,1)+F(3,2)*A(3,2)+F(3,4)*A(3,4)+F(3,5)*A(3,5)
     1+F(3,6)*A(3,6)
      R4=F(4,1)*A(4,1)+F(4,2)*A(4,2)+F(4,3)*A(4,3)+F(4,5)*A(4,5)
     1+F(4,6)*A(4,6)
      R5=F(5,1)*A(5,1)+F(5,2)*A(5,2)+F(5,3)*A(5,3)+F(5,4)*A(5,4)
     1+F(5,6)*A(5,6)
      R6=F(6,1)*A(6,1)+F(6,2)*A(6,2)+F(6,3)*A(6,3)+F(6,4)*A(6,4)
     1+F(6,5)*A(6,5)
C
      S1=AM2*F(2,1)*T(2,1)
      S2=AM3*F(3,1)*T(3,1)
      S3=AM4*F(4,1)*T(4,1)
      S4=AM5*F(5,1)*T(5,1)
      S5=AM6*F(6,1)*T(6,1)
```

```
C
      S6=AM1*F(1,2)*T(1,2)
      S7=AM3*F(3,2)*T(3,2)
      S8=AM4*F(4,2)*T(4,2)
      S9=AM5*F(5,2)*T(5,2)
      S10=AM6*F(6,2)*T(6,2)
C
      S11=AM1*F(1,3)*T(1,3)
      S12=AM2*F(2,3)*T(2,3)
      S13=AM4*F(4,3)*T(4,3)
      S14=AM5*F(5,3)*T(5,3)
      S15=AM6*F(6,3)*T(6,3)
C
      S16=AM1*F(1,4)*T(1,4)
      S17=AM2*F(2,4)*T(2,4)
      S18=AM3*F(3,4)*T(3,4)
      S19=AM5*F(5,4)*T(5,4)
      S20=AM6*F(6,4)*T(6,4)
C
      S21=AM1*F(1,5)*T(1,5)
      S22=AM2*F(2,5)*T(2,5)
      S23=AM3*F(3,5)*T(3,5)
      S24=AM4*F(4,5)*T(4,5)
      S25=AM6*F(6,5)*T(6,5)
C
      S26=AM1*F(1,6)*T(1,6)
      S27=AM2*F(2,6)*T(2,6)
      S28=AM3*F(3,6)*T(3,6)
      S29=AM4*F(4,6)*T(4,6)
      S30=AM5*F(5,6)*T(5,6)
C
      WRITE(7,76)
      WRITE(7,77)
      WRITE(7,78)
      WRITE(7,79)
      WRITE(7,80)
      WRITE(7,81)
      WRITE(7,82)
      WRITE(7,83)
      WRITE(7,84)
      QNET=QFIRE
C
C  RADIANT FLUX
C
 250  T4G=SIGMA*(TG+460.0)**4.0
      T4MG=SIGMA*(TMG+460.0)**4.0
      T4W1=SIGMA*(TW1+460.0)**4.0
      T4W2=SIGMA*(TW2+460.0)**4.0
      T4W3=SIGMA*(TW3+460.0)**4.0
      T4W4=SIGMA*(TW4+460.0)**4.0
      T4W5=SIGMA*(TW5+460.0)**4.0
      T4W6=SIGMA*(TW6+460.0)**4.0
```

```
C
      T4MW2=SIGMA*(TMW2+460.0)**4.0
      T4MW3=SIGMA*(TMW3+460.0)**4.0
      T4MW4=SIGMA*(TMW4+460.0)**4.0
      T4MW5=SIGMA*(TMW5+460.0)**4.0
      T4MW6=SIGMA*(TMW6+460.0)**4.0
C
      T4G2=SIGMA*(TG2+460.0)**4.0
      T4G3=SIGMA*(TG3+460.0)**4.0
      T4G4=SIGMA*(TG4+460.0)**4.0
      T4G5=SIGMA*(TG5+460.0)**4.0
      T4G6=SIGMA*(TG6+460.0)**4.0
C
      T4AW2=SIGMA*(TAW2+460.0)**4.0
      T4AW3=SIGMA*(TAW3+460.0)**4.0
      T4AW4=SIGMA*(TAW4+460.0)**4.0
      T4AW5=SIGMA*(TAW5+460.0)**4.0
      T4AW6=SIGMA*(TAW6+460.0)**4.0
C
C ENERGY EQUATIONS
C
      DTG=(QNET+(T4W1+T4W3)*AC1+(T4W2+T4W4)*AC2+(T4W5+T4W6)*AC5-(T4G
     1*COMPAR)-(HC*(((TG-TW1)+(TG-TW3))*AC1+((TG-TW2)+(TG-TW4))*AC2
     1+((TG-TW5)+(TG-TW6))*AC5)))*TI/(DCO*COMPV*CCOGAS)
C
      DTMG=((T4W1*R1*AM1)+(T4MW2*R2*AM2)+(T4MW3*R3*AM3)+(T4MW4*R4*AM4
     1)+(T4MW5*R5*AM5)+(T4MW6*R6*AM6)-(EMMGAS*T4MG*MAGAR)-(HCMAG*(((
     1TMG-TW1)*AM1)+((TMG-TMW2)*AM2)+((TMG-TMW3)*AM3)+((TMG-TMW4)*AM4
     1)+((TMG-TMW5)*AM5)+((TMG-TMW6)*AM6))))*TI/(DAIR*MAGV*CAIR)
C
      DTW1=(AM1*(T4G+(EMMGAS*T4MG)+(HC*(TG-TW1))-2.0*T4W1-(HCMAG*(TW1
     1-TMG)))+S1*T4MW2+S2*T4MW3+S3*T4MW4+S4*T4MW5+S5*T4MW6)*TI/(DST*
     1WT1*AM1*CST)
C
      DTMW2=(AM2*(EMMGAS*T4MG+T4IN-(2.0*T4MW2)+(HCMAG*(TMG-TMW2))-
     1(HCO*(TMW2-TINIT)))+S6*T4W1+S7*T4MW3+S8*T4MW4+S9*T4MW5+S10*
     1T4MW6)*TI/(DST*WTM2*AM2*CST)
C
      DTMW3=(AM3*(EMMGAS*T4MG+T4IN-(2.0*T4MW3)+(HCMAG*(TMG-TMW3))-
     1(HCO*(TMW3-TINIT)))+S11*T4W1+S12*T4MW2+S13*T4MW4+S14*T4MW5+
     1S15*T4MW6)*TI/(DST*WTM3*AM3*CST)
C
      DTMW4=(AM4*(EMMGAS*T4MG+T4IN-(2.0*T4MW4)+(HCMAG*(TMG-TMW4))-
     1(HCO*(TMW4-TINIT)))+S16*T4W1+S17*T4MW2+S18*T4MW3+S19*T4MW5+
     1S20*T4MW6)*TI/(DST*WTM4*AM4*CST)
C
      DTMW5=(AM5*(EMMGAS*T4MG+T4IN-(2.0*T4MW5)+(HCMAG*(TMG-TMW5))-
     1(HCO*(TMW5-TINIT)))+S21*T4W1+S22*T4MW2+S23*T4MW3+S24*T4MW4+
     1S25*T4MW6)*TI/(DST*WTM5*AM5*CST)
C
      DTMW6=(AM6*(EMMGAS*T4MG+T4IN-(2.0*T4MW6)+(HCMAG*(TMG-TMW6))-
     1(HCO*(TMW6-TINIT)))+S26*T4W1+S27*T4MW2+S28*T4MW3+S29*T4MW4+
     1S30*T4MW5)*TI/(DST*WTM6*AM6*CST)
```

```
C
      DTW2=(T4G-(2.0*T4W2)+T4G2+(HC*(TG-TW2))-(HCMAG*(TW2-TG2)))*
     1TI/(DST*WT2*CST)
C
      DTW3=(T4G-(2.0*T4W3)+T4G3+(HC*(TG-TW3))-(HCMAG*(TW3-TG3)))*
     1TI/(DST*WT3*CST)
C
      DTW4=(T4G-(2.0*T4W4)+T4G4+(HC*(TG-TW4))-(HCMAG*(TW4-TG4)))*
     1TI/(DST*WT4*CST)
C
      DTW5=(T4G-(2.0*T4W5)+T4G5+(HC*(TG-TW5))-(HCMAG*(TW5-TG5)))*
     1TI/(DST*WT5*CST)
C
      DTW6=(T4G-(2.0*T4W6)+T4G6+(HC*(TG-TW6))-(HCMAG*(TW6-TG6)))*
     1TI/(DST*WT6*CST)
C
      DTG2=(AC2*(T4W2-T4G2+(HCMAG*(TW2-TG2)))+AAC2*(T4AW2-T4G2-
     1(HCMAG*(TG2-TAW2))))*TI/(DAIR*COMP2V*CAIR)
C
      DTG3=(AC3*(T4W3-T4G3+(HCMAG*(TW3-TG3)))+AAC3*(T4AW3-T4G3-
     1(HCMAG*(TG3-TAW3))))*TI/(DAIR*COMP3V*CAIR)
C
      DTG4=(AC4*(T4W4-T4G4+(HCMAG*(TW4-TG4)))+AAC4*(T4AW4-T4G4-
     1(HCMAG*(TG4-TAW4))))*TI/(DAIR*COMP4V*CAIR)
C
      DTG5=(AC5*(T4W5-T4G5+(HCMAG*(TW5-TG5)))+AAC5*(T4AW5-T4G5-
     1(HCMAG*(TG5-TAW5))))*TI/(DAIR*COMP5V*CAIR)
C
      DTG6=(AC6*(T4W6-T4G6+(HCMAG*(TW6-TG6)))+AAC6*(T4AW6-T4G6-
     1(HCMAG*(TG6-TAW6))))*TI/(DAIR*COMP6V*CAIR)
C
      DTAW2=(T4G2+(HCMAG*(TG2-TAW2))-(2.0*T4AW2)+T4IN-(HCO*(TAW2-
     1TINIT)))*TI/(DST*WTA2*CST)
C
      DTAW3=(T4G3+(HCMAG*(TG3-TAW3))-(2.0*T4AW3)+T4IN-(HCO*(TAW3-
     1TINIT)))*TI/(DST*WTA3*CST)
C
      DTAW4=(T4G4+(HCMAG*(TG4-TAW4))-(2.0*T4AW4)+T4IN-(HCO*(TAW4-
     1TINIT)))*TI/(DST*WTA4*CST)
C
      DTAW5=(T4G5+(HCMAG*(TG5-TAW5))-(2.0*T4AW5)+T4IN-(HCO*(TAW5-
     1TINIT)))*TI/(DST*WTA5*CST)
C
      DTAW6=(T4G6+(HCMAG*(TG6-TAW6))-(2.0*T4AW6)+T4IN-(HCO*(TAW6-
     1TINIT)))*TI/(DST*WTA6*CST)
C
C TEMPERATURE EVALUATION
C
      TIM=TIM+TI
C
      TG=TG+DTG
      TMG=TMG+DTMG
      TW1=TW1+DTW1
      TW2=TW2+DTW2
```

```
      TW3=TW3+DTW3
      TW4=TW4+DTW4
      TW5=TW5+DTW5
      TW6=TW6+DTW6
      TMW2=TMW2+DTMW2
      TMW3=TMW3+DTMW3
      TMW4=TMW4+DTMW4
      TMW5=TMW5+DTMW5
      TMW6=TMW6+DTMW6
      TG2=TG2+DTG2
      TG3=TG3+DTG3
      TG4=TG4+DTG4
      TG5=TG5+DTG5
      TG6=TG6+DTG6
      TAW2=TAW2+DTAW2
      TAW3=TAW3+DTAW3
      TAW4=TAW4+DTAW4
      TAW5=TAW5+DTAW5
      TAW6=TAW6+DTAW6
      QESCAP=DK*(TG-TINIT)
      QNET=QFIRE-QESCAP
      NTI=NTI+1
      IF(NTI .GT. 16200)GO TO 110
      IF(NTI .EQ. 3600)GO TO 254
      IF(NTI .GT. 3600)GO TO 256
      IF(NTI .EQ. 180)GO TO 260
      IF(NTI .EQ. 360)GO TO 260
      IF(NTI .EQ. 270)GO TO 260
      IF(NTI .EQ. 450)GO TO 260
      IF(NTI .EQ. 540)GO TO 260
      IF(NTI .EQ. 720)GO TO 260
      IF(NTI .EQ. 900)GO TO 260
      IF(NTI .EQ. 1350)GO TO 260
      IF(NTI .EQ. 1800)GO TO 260
      IF(NTI .EQ. 2250)GO TO 260
      IF(NTI .EQ. 2700)GO TO 260
      IF(NTI .EQ. 3150)GO TO 260
      GO TO 250
254   TI=2.0*TI
      GO TO 260
256   IF(NTI .EQ. 4050)GO TO 260
      IF(NTI .EQ. 4500)GO TO 260
      IF(NTI .EQ. 4950)GO TO 260
      IF(NTI .EQ. 5400)GO TO 260
      IF(NTI .EQ. 6300)GO TO 260
      IF(NTI .EQ. 7200)GO TO 260
      IF(NTI .EQ. 8100)GO TO 260
      IF(NTI .EQ. 9000)GO TO 260
      IF(NTI .EQ. 10800)GO TO 260
      IF(NTI .EQ. 12600)GO TO 260
      IF(NTI .EQ. 14400)GO TO 260
      IF(NTI .EQ. 16200)GO TO 260
      GO TO 250
```

```
260  WRITE(7,85)TIM,TG,TMG,TW1
     WRITE(7,86)TW2,TW3,TW4,TW5,TW6
     WRITE(7,87)TMW2,TMW3,TMW4,TMW5,TMW6
     WRITE(7,88)TG2,TG3,TG4,TG5,TG6
     WRITE(7,89)TAW2,TAW3,TAW4,TAW5,TAW6
     GO TO 250
110  STOP
     END
```

APPENDIX B. EXAMPLE OUTPUT OF MFIRE

```
FIRE DIAMETER (FT)
       4.00

FIRE COMP DIMENSIONS (FT)   MAG DIMENSIONS (FT)
    LE    WI    HT            LE    WI    HT
   30.0  20.0  10.0          30.0  20.0  10.0

DIMENSIONS FOR ADJACENT COMPARTMENTS 2,3,4,5 & 6
  COMPW2   COMPL3   COMPW4   COMPH5   COMPH6
  15.00    15.00    15.00    10.00    10.00

FUEL COMBUSTION ENERGY (BTU/LB)
   20000.0
FRACTION OF ENERGY LOST BEFORE STIRRING
  0.00

DENSITIES (LB/FT^3)
 STEEL   AIR    COMB GAS
 490.1  0.0805  0.0900

SPECIFIC HEATS (BTU/LB-F)
 STEEL   AIR    COMB GAS
 0.118  0.240   0.335

WALL THICKNESSES (INCHES)
 FIRE COMP SURFACES 1,2,3,4,5 & 6
  0.500  0.500  0.500  0.500  0.500  0.500
 MAGAZINE SURFACES 2,3,4,5 & 6
         0.500  0.500  0.500  0.500  0.500
 ADJACENT COMPARTMENTS 2,3,4,5 & 6
         0.500  0.500  0.500  0.500  0.500

HEAT TRANSFER COEFFS IN FIRE COMP, IN MAG & ADJ
 COMPS, & OUTSIDE MAG & ADJ COMPS (BTU/FT^2-HR-F)
      COMP          MAG          OUTSIDE
      0.48          0.36          0.36


INPUT EMISSIVITY OF MAGAZINE GAS
0.230E+00

RADIATION ABSORPTION COEFF. OF MAG GAS, 1/FT
0.100E-01


ORDNANCE DIAMETER (FT)
 1.000

DISTANCE FROM ORDNANCE AXIS TO DECK (FT)
 5.000

DISTANCE FROM ORDNANCE AXIS TO COMMON BULKHEAD(FT)
 1.000

DISTANCE FROM SELECTED POINT OF INTEREST ALONG
ORDNANCE AXIS TO EITHER SIDE BULKHEAD OF MAG (FT)
10.000

ORDNANCE SEGMENT ANGLE (DEGREES)
 15.000

NUMBER OF HORIZONTAL BULKHEAD SEGMENTS
 10

NUMBER OF VERTICAL BULKHEAD SEGMENTS
 16
```

RADIANT ENERGY ABSORBED BY MAGAZINE GAS

FROM WALL NO.	TO WALL NO.	DISTANCE FEET	FRACTION ABSORBED
1	2	18.03	0.16496E+00
1	3	30.00	0.25918E+00
1	4	18.03	0.16496E+00
1	5	15.81	0.14625E+00
1	6	15.81	0.14625E+00
2	1	18.03	0.16496E+00
2	3	18.03	0.16496E+00
2	4	20.00	0.18127E+00
2	5	11.18	0.10578E+00
2	6	11.18	0.10578E+00
3	1	30.00	0.25918E+00
3	2	18.03	0.16496E+00
3	4	18.03	0.16496E+00
3	5	15.81	0.14625E+00
3	6	15.81	0.14625E+00
4	1	18.03	0.16496E+00
4	2	20.00	0.18127E+00
4	3	18.03	0.16496E+00
4	5	11.18	0.10578E+00
4	6	11.18	0.10578E+00
5	1	15.81	0.14625E+00
5	2	11.18	0.10578E+00
5	3	15.81	0.14625E+00
5	4	11.18	0.10578E+00
5	6	10.00	0.95163E-01
6	1	15.81	0.14625E+00
6	2	11.18	0.10578E+00
6	3	15.81	0.14625E+00
6	4	11.18	0.10578E+00
6	5	10.00	0.95163E-01

MAGAZINE VIEW FACTORS

FROM WALL NO.	TO WALL NO.	VIEW FACTOR
1	2	0.16169E+00
1	3	0.60331E-01
1	4	0.16169E+00
1	5	0.30814E+00
1	6	0.30814E+00
2	1	0.10780E+00
2	3	0.10780E+00
2	4	0.14641E+00
2	5	0.31900E+00
2	6	0.31900E+00
3	1	0.60331E-01
3	2	0.16169E+00
3	4	0.16169E+00
3	5	0.30814E+00
3	6	0.30814E+00
4	1	0.10780E+00
4	2	0.14641E+00
4	3	0.10780E+00
4	5	0.31900E+00
4	6	0.31900E+00
5	1	0.10271E+00
5	2	0.15950E+00
5	3	0.10271E+00
5	4	0.15950E+00
5	6	0.47558E+00
6	1	0.10271E+00
6	2	0.15950E+00
6	3	0.10271E+00

6	4	0.15950E+00
6	5	0.47558E+00

RADIATION FROM COMMON BULKHEAD ON ORDNANCE

THETA (ORDNANCE ANGLE)=ANGLE BETWEEN LINE PERPENDICULAR TO COMMON BULKHEAD THROUGH ORDNANCE AXIS AND LINE FROM ORDNANCE AXIS TO ORDNANCE SURFACE ELEMENT

FLUX=INCIDENT FLUX (BTU/FT^2-HR) ON ORDNANCE SURFACE AT ORDNANCE ANGLE THETA FOR INDICATED TEMPERATURE OF COMMON BULKHEAD

ENG=INCIDENT ENERGY PER UNIT TIME (BTU/HOUR) ON ORDNANCE SURFACE ELEMENT AT THETA FOR INDICATED TEMP OF COMMON BULKHEAD

THETA			
FLUX(400F)	FLUX(600F)	FLUX(800F)	FLUX(1000F)
ENG(400F)	ENG(600F)	ENG(800F)	ENG(1000F)
7.5			
0.740E+03	0.171E+04	0.341E+04	0.614E+04
0.968E+02	0.223E+03	0.446E+03	0.804E+03
22.5			
0.734E+03	0.169E+04	0.338E+04	0.609E+04
0.960E+02	0.222E+03	0.442E+03	0.798E+03
37.5			
0.711E+03	0.164E+04	0.327E+04	0.590E+04
0.930E+02	0.215E+03	0.429E+03	0.773E+03
52.5			
0.650E+03	0.150E+04	0.300E+04	0.540E+04
0.851E+02	0.196E+03	0.392E+03	0.707E+03
67.5			
0.550E+03	0.127E+04	0.253E+04	0.457E+04
0.720E+02	0.166E+03	0.332E+03	0.598E+03
82.5			
0.429E+03	0.990E+03	0.198E+04	0.356E+04
0.561E+02	0.130E+03	0.259E+03	0.466E+03
97.5			
0.301E+03	0.694E+03	0.139E+04	0.250E+04
0.394E+02	0.909E+02	0.181E+03	0.327E+03
112.5			
0.184E+03	0.425E+03	0.849E+03	0.153E+04
0.241E+02	0.557E+02	0.111E+03	0.200E+03
127.5			
0.908E+02	0.210E+03	0.418E+03	0.754E+03
0.119E+02	0.274E+02	0.548E+02	0.987E+02
142.5			
0.304E+02	0.701E+02	0.140E+03	0.252E+03
0.397E+01	0.917E+01	0.183E+02	0.330E+02
157.5			
0.217E+01	0.500E+01	0.999E+01	0.180E+02
0.284E+00	0.655E+00	0.131E+01	0.236E+01

```
      172.5
 0.000E+00  0.000E+00  0.000E+00  0.000E+00
 0.000E+00  0.000E+00  0.000E+00  0.000E+00

       -7.5
 0.740E+03  0.171E+04  0.341E+04  0.614E+04
 0.968E+02  0.223E+03  0.446E+03  0.804E+03

      -22.5
 0.734E+03  0.169E+04  0.338E+04  0.609E+04
 0.960E+02  0.222E+03  0.442E+03  0.798E+03

      -37.5
 0.711E+03  0.164E+04  0.327E+04  0.590E+04
 0.930E+02  0.215E+03  0.429E+03  0.773E+03

      -52.5
 0.650E+03  0.150E+04  0.300E+04  0.540E+04
 0.851E+02  0.196E+03  0.392E+03  0.707E+03

      -67.5
 0.550E+03  0.127E+04  0.253E+04  0.457E+04
 0.720E+02  0.166E+03  0.332E+03  0.598E+03

      -82.5
 0.429E+03  0.990E+03  0.198E+04  0.356E+04
 0.561E+02  0.130E+03  0.259E+03  0.466E+03

      -97.5
 0.301E+03  0.694E+03  0.139E+04  0.250E+04
 0.394E+02  0.909E+02  0.181E+03  0.327E+03

     -112.5
 0.184E+03  0.425E+03  0.849E+03  0.153E+04
 0.241E+02  0.557E+02  0.111E+03  0.200E+03

     -127.5
 0.908E+02  0.210E+03  0.418E+03  0.754E+03
 0.119E+02  0.274E+02  0.548E+02  0.987E+02

     -142.5
 0.304E+02  0.701E+02  0.140E+03  0.252E+03
 0.397E+01  0.917E+01  0.183E+02  0.330E+02

     -157.5
 0.217E+01  0.500E+01  0.999E+01  0.180E+02
 0.284E+00  0.655E+00  0.131E+01  0.236E+01

CALCULATED EMISSIVITY OF MAGAZINE GAS
      0.148E+00


   GAS & WALL TEMPS WITH TIME

            TEMP-F    TEMP-F    TEMP-F    TEMP-F    TEMP-F
   TIME
    HR
           FC GAS    MAG GAS   COM WALL
            2         3         4         5         6     # FC WALL
             2         3         4         5         6    # MAG WALL
              2         3         4         5         6   # ADJ C GAS
               2         3         4         5         6  # ADJ C WALL

  0.050     809.29     69.52    142.90
             142.99    142.99    142.99    143.02    143.02
```

	70.60	70.48	70.60	70.65	70.65
	76.09	75.93	76.09	79.05	79.05
	70.54	70.54	70.54	70.56	70.56
0.075	815.56	70.46	188.22		
	188.45	188.44	188.45	188.54	188.54
	70.73	70.52	70.73	70.81	70.81
	83.47	83.01	83.47	90.60	90.60
	70.66	70.66	70.66	70.76	70.76
0.100	822.58	72.35	232.43		
	232.91	232.89	232.91	233.15	233.15
	70.94	70.60	70.94	71.04	71.04
	93.13	92.17	93.13	105.70	105.70
	70.91	70.89	70.91	71.15	71.15
0.125	830.48	75.09	275.37		
	276.23	276.19	276.23	276.71	276.71
	71.25	70.74	71.25	71.37	71.37
	104.63	103.00	104.63	123.54	123.54
	71.31	71.28	71.31	71.81	71.81
0.150	839.26	78.59	316.89		
	318.28	318.21	318.28	319.11	319.11
	71.68	70.95	71.68	71.82	71.82
	117.66	115.26	117.66	143.50	143.50
	71.91	71.84	71.91	72.78	72.78
0.200	859.23	87.56	395.12		
	398.02	397.86	398.02	399.93	399.93
	72.95	71.60	72.95	73.11	73.11
	147.34	143.13	147.34	187.62	187.62
	73.78	73.60	73.78	75.88	75.88
0.250	881.76	98.79	466.14		
	471.15	470.82	471.15	474.64	474.64
	74.86	72.65	74.86	75.02	75.02
	179.96	173.83	179.96	234.07	234.07
	76.74	76.36	76.74	80.85	80.85
0.375	941.85	133.49	609.13		
	621.02	620.09	621.02	629.96	629.96
	82.86	77.24	82.86	82.95	82.95
	260.65	250.23	260.65	342.22	342.22
	89.93	88.57	89.93	103.16	103.16
0.500	994.22	170.99	705.33		
	723.72	722.14	723.72	738.05	738.05
	95.34	84.74	95.34	95.29	95.29
	325.23	311.84	325.23	424.90	424.90
	111.39	108.36	111.39	139.63	139.63
0.625	1031.50	204.67	765.20		
	787.98	785.92	787.98	806.26	806.26
	111.14	94.64	111.14	110.90	110.90
	371.00	355.69	371.00	482.59	482.59
	138.95	133.73	138.95	186.14	186.14
0.750	1055.34	232.02	800.82		
	826.27	823.88	826.27	847.31	847.31
	128.66	106.09	128.66	128.22	128.22
	403.02	386.40	403.02	523.08	523.08
	169.37	161.77	169.37	236.50	236.50
0.875	1070.26	253.61	821.94		
	849.14	846.49	849.14	872.39	872.39
	146.53	118.33	146.53	145.92	145.92

	426.63	409.02	426.63	553.39	553.39
	199.95	190.03	199.95	285.36	285.36
1.000	1080.04	271.05	835.01		
	863.56	860.69	863.56	888.79	888.79
	163.82	130.80	163.82	163.09	163.09
	445.40	426.97	445.40	577.64	577.64
	228.88	216.90	228.88	329.27	329.27
1.250	1092.39	298.32	850.34		
	881.09	877.82	881.09	909.63	909.63
	194.95	155.07	194.95	194.10	194.10
	474.90	455.22	474.90	614.40	614.40
	278.53	263.48	278.53	397.28	397.28
1.500	1100.42	319.37	859.89		
	892.39	888.82	892.39	923.01	923.01
	220.60	177.22	220.60	219.79	219.79
	497.27	476.85	497.27	639.15	639.15
	316.08	299.36	316.08	440.55	440.55
1.750	1105.99	335.94	866.72		
	900.47	896.69	900.47	931.97	931.97
	241.00	196.51	241.00	240.31	240.31
	513.82	493.11	513.82	654.80	654.80
	342.94	325.57	342.94	466.17	466.17
2.000	1109.75	348.79	871.60		
	906.13	902.24	906.13	937.78	937.78
	256.82	212.65	256.82	256.27	256.27
	525.53	504.84	525.53	664.27	664.27
	361.42	344.03	361.42	480.85	480.85
2.500	1113.78	365.84	877.36		
	912.46	908.54	912.46	943.68	943.68
	277.83	235.85	277.83	277.54	277.54
	538.78	518.51	538.78	673.16	673.16
	381.91	365.15	381.91	493.94	493.94
3.000	1115.40	375.13	880.03		
	915.11	911.22	915.11	945.91	945.91
	289.30	249.46	289.30	289.18	289.18
	544.43	524.56	544.43	676.25	676.25
	390.53	374.42	390.53	498.25	498.25
3.500	1116.05	380.00	881.27		
	916.19	912.33	916.19	946.76	946.76
	295.34	256.89	295.34	295.31	295.31
	546.74	527.13	546.74	677.35	677.35
	394.04	378.34	394.04	499.73	499.73
4.000	1116.31	382.50	881.85		
	916.62	912.79	916.62	947.09	947.09
	298.44	260.78	298.44	298.46	298.46
	547.67	528.20	547.67	677.76	677.76
	395.45	379.97	395.45	500.26	500.26
5.000	1116.46	384.40	882.24		
	916.86	913.05	916.86	947.28	947.28
	300.81	263.79	300.81	300.87	300.87
	548.19	528.82	548.19	677.98	677.98
	396.24	380.92	396.24	500.54	500.54
6.000	1116.49	384.88	882.33		
	916.91	913.09	916.91	947.30	947.30
	301.41	264.56	301.41	301.47	301.47
	548.27	528.92	548.27	678.02	678.02

	396.36	381.08	396.36	500.58	500.58
7.000	1116.49	384.99	882.35		
	916.91	913.10	916.91	947.30	947.30
	301.55	264.75	301.55	301.62	301.62
	548.28	528.94	548.28	678.02	678.02
	396.37	381.10	396.37	500.58	500.58
8.000	1116.49	385.02	882.35		
	916.91	913.10	916.91	947.30	947.30
	301.58	264.79	301.58	301.65	301.65
	548.28	528.94	548.28	678.02	678.02
	396.37	381.10	396.37	500.58	500.58

FIRE DIAMETER (FT)
3.00

FIRE COMP DIMENSIONS (FT)   MAG DIMENSIONS (FT)

LE	WI	HT	LE	WI	HT
30.0	20.0	10.0	30.0	20.0	10.0

DIMENSIONS FOR ADJACENT COMPARTMENTS 2,3,4,5 & 6

COMPW2	COMPL3	COMPW4	COMPH5	COMPH6
15.00	15.00	15.00	10.00	10.00

FUEL COMBUSTION ENERGY (BTU/LB)
20000.0
FRACTION OF ENERGY LOST BEFORE STIRRING
0.00

DENSITIES (LB/FT^3)

STEEL	AIR	COMB GAS
490.1	0.0805	0.0900

SPECIFIC HEATS (BTU/LB-F)

STEEL	AIR	COMB GAS
0.118	0.240	0.335

WALL THICKNESSES (INCHES)
FIRE COMP SURFACES 1,2,3,4,5 & 6
0.500 0.500 0.500 0.500 0.500 0.500
MAGAZINE SURFACES 2,3,4,5 & 6
0.500 0.500 0.500 0.500 0.500
ADJACENT COMPARTMENTS 2,3,4,5 & 6
0.500 0.500 0.500 0.500 0.500

HEAT TRANSFER COEFFS IN FIRE COMP, IN MAG & ADJ
COMPS, & OUTSIDE MAG & ADJ COMPS (BTU/FT^2-HR-F)

COMP	MAG	OUTSIDE
0.48	0.36	0.36

INPUT EMISSIVITY OF MAGAZINE GAS
0.230E+00

RADIATION ABSORPTION COEFF OF MAG GAS, 1/FT
0.100E-01

ORDNANCE DIAMETER (FT)
1.000

DISTANCE FROM ORDNANCE AXIS TO DECK (FT)
5.000

DISTANCE FROM ORDNANCE AXIS TO COMMON BULKHEAD(FT)
1.000

DISTANCE FROM SELECTED POINT OF INTEREST ALONG
ORDNANCE AXIS TO EITHER SIDE BULKHEAD OF MAG (FT)
10.000

ORDNANCE SEGMENT ANGLE (DEGREES)
15.000

NUMBER OF HORIZONTAL BULKHEAD SEGMENTS
10

NUMBER OF VERTICAL BULKHEAD SEGMENTS
16

RADIANT ENERGY ABSORBED BY MAGAZINE GAS

FROM WALL NO.	TO WALL NO.	DISTANCE FEET	FRACTION ABSORBED
1	2	18.03	0.16496E+00
1	3	30.00	0.25918E+00
1	4	18.03	0.16496E+00
1	5	15.81	0.14625E+00
1	6	15.81	0.14625E+00
2	1	18.03	0.16496E+00
2	3	18.03	0.16496E+00
2	4	20.00	0.18127E+00
2	5	11.18	0.10578E+00
2	6	11.18	0.10578E+00
3	1	30.00	0.25918E+00
3	2	18.03	0.16496E+00
3	4	18.03	0.16496E+00
3	5	15.81	0.14625E+00
3	6	15.81	0.14625E+00
4	1	18.03	0.16496E+00
4	2	20.00	0.18127E+00
4	3	18.03	0.16496E+00
4	5	11.18	0.10578E+00
4	6	11.18	0.10578E+00
5	1	15.81	0.14625E+00
5	2	11.18	0.10578E+00
5	3	15.81	0.14625E+00
5	4	11.18	0.10578E+00
5	6	10.00	0.95163E-01
6	1	15.81	0.14625E+00
6	2	11.18	0.10578E+00
6	3	15.81	0.14625E+00
6	4	11.18	0.10578E+00
6	5	10.00	0.95163E-01

MAGAZINE VIEW FACTORS

FROM WALL NO.	TO WALL NO.	VIEW FACTOR
1	2	0.16169E+00
1	3	0.60331E-01
1	4	0.16169E+00
1	5	0.30814E+00
1	6	0.30814E+00
2	1	0.10780E+00
2	3	0.10780E+00
2	4	0.14641E+00
2	5	0.31900E+00
2	6	0.31900E+00
3	1	0.60331E-01
3	2	0.16169E+00
3	4	0.16169E+00
3	5	0.30814E+00
3	6	0.30814E+00
4	1	0.10780E+00
4	2	0.14641E+00
4	3	0.10780E+00
4	5	0.31900E+00
4	6	0.31900E+00
5	1	0.10271E+00
5	2	0.15950E+00
5	3	0.10271E+00
5	4	0.15950E+00
5	6	0.47558E+00
6	1	0.10271E+00
6	2	0.15950E+00
6	3	0.10271E+00

6	4	0.15950E+00
6	5	0.47558E+00

RADIATION FROM COMMON BULKHEAD ON ORDNANCE

THETA (ORDNANCE ANGLE)=ANGLE BETWEEN LINE PERPENDICULAR TO COMMON BULKHEAD THROUGH ORDNANCE AXIS AND LINE FROM ORDNANCE AXIS TO ORDNANCE SURFACE ELEMENT

FLUX=INCIDENT FLUX (BTU/FT^2-HR) ON ORDNANCE SURFACE AT ORDNANCE ANGLE THETA FOR INDICATED TEMPERATURE OF COMMON BULKHEAD

ENG=INCIDENT ENERGY PER UNIT TIME (BTU/HOUR) ON ORDNANCE SURFACE ELEMENT AT THETA FOR INDICATED TEMP OF COMMON BULKHEAD

THETA			
FLUX(400F)	FLUX(600F)	FLUX(800F)	FLUX(1000F)
ENG(400F)	ENG(600F)	ENG(800F)	ENG(1000F)
7.5			
0.740E+03	0.171E+04	0.341E+04	0.614E+04
0.968E+02	0.223E+03	0.446E+03	0.804E+03
22.5			
0.734E+03	0.169E+04	0.338E+04	0.609E+04
0.960E+02	0.222E+03	0.442E+03	0.798E+03
37.5			
0.711E+03	0.164E+04	0.327E+04	0.590E+04
0.930E+02	0.215E+03	0.429E+03	0.773E+03
52.5			
0.650E+03	0.150E+04	0.300E+04	0.540E+04
0.851E+02	0.196E+03	0.392E+03	0.707E+03
67.5			
0.550E+03	0.127E+04	0.253E+04	0.457E+04
0.720E+02	0.166E+03	0.332E+03	0.598E+03
82.5			
0.429E+03	0.990E+03	0.198E+04	0.356E+04
0.561E+02	0.130E+03	0.259E+03	0.466E+03
97.5			
0.301E+03	0.694E+03	0.139E+04	0.250E+04
0.394E+02	0.909E+02	0.181E+03	0.327E+03
112.5			
0.184E+03	0.425E+03	0.849E+03	0.153E+04
0.241E+02	0.557E+02	0.111E+03	0.200E+03
127.5			
0.908E+02	0.210E+03	0.418E+03	0.754E+03
0.119E+02	0.274E+02	0.548E+02	0.987E+02
142.5			
0.304E+02	0.701E+02	0.140E+03	0.252E+03
0.397E+01	0.917E+01	0.183E+02	0.330E+02
157.5			
0.217E+01	0.500E+01	0.999E+01	0.180E+02
0.284E+00	0.655E+00	0.131E+01	0.236E+01

```
        172.5
    0.000E+00  0.000E+00  0.000E+00  0.000E+00
    0.000E+00  0.000E+00  0.000E+00  0.000E+00

         -7.5
    0.740E+03  0.171E+04  0.341E+04  0.614E+04
    0.968E+02  0.223E+03  0.446E+03  0.804E+03

        -22.5
    0.734E+03  0.169E+04  0.338E+04  0.609E+04
    0.960E+02  0.222E+03  0.442E+03  0.798E+03

        -37.5
    0.711E+03  0.164E+04  0.327E+04  0.590E+04
    0.930E+02  0.215E+03  0.429E+03  0.773E+03

        -52.5
    0.650E+03  0.150E+04  0.300E+04  0.540E+04
    0.851E+02  0.196E+03  0.392E+03  0.707E+03

        -67.5
    0.550E+03  0.127E+04  0.253E+04  0.457E+04
    0.720E+02  0.166E+03  0.332E+03  0.598E+03

        -82.5
    0.429E+03  0.990E+03  0.198E+04  0.356E+04
    0.561E+02  0.130E+03  0.259E+03  0.466E+03

        -97.5
    0.301E+03  0.694E+03  0.139E+04  0.250E+04
    0.394E+02  0.909E+02  0.181E+03  0.327E+03

       -112.5
    0.184E+03  0.425E+03  0.849E+03  0.153E+04
    0.241E+02  0.557E+02  0.111E+03  0.200E+03

       -127.5
    0.908E+02  0.210E+03  0.418E+03  0.754E+03
    0.119E+02  0.274E+02  0.548E+02  0.987E+02

       -142.5
    0.304E+02  0.701E+02  0.140E+03  0.252E+03
    0.397E+01  0.917E+01  0.183E+02  0.330E+02

       -157.5
    0.217E+01  0.500E+01  0.999E+01  0.180E+02
    0.284E+00  0.655E+00  0.131E+01  0.236E+01

CALCULATED EMISSIVITY OF MAGAZINE GAS
      0.148E+00


   GAS & WALL TEMPS WITH TIME

            TEMP-F    TEMP-F    TEMP-F    TEMP-F    TEMP-F
   TIME
    HR
           FC GAS    MAG GAS   COM WALL
            2          3          4          5          6     # FC WALL
             2          3          4          5          6    # MAG WALL
              2          3          4          5          6   # ADJ C GAS
               2          3          4          5          6  # ADJ C WALL

  0.050    643.31     68.90     108.59
            108.66    108.65    108.66    108.67    108.67
```

	70.56	70.46	70.56	70.62	70.62
	73.27	73.18	73.27	74.71	74.71
	70.52	70.51	70.52	70.53	70.53
0.075	650.15	68.94	134.99		
	135.14	135.14	135.14	135.19	135.19
	70.63	70.46	70.63	70.71	70.71
	76.90	76.67	76.90	80.42	80.42
	70.57	70.57	70.57	70.62	70.62
0.100	655.18	69.58	160.95		
	161.23	161.22	161.23	161.35	161.35
	70.73	70.48	70.73	70.83	70.83
	81.59	81.11	81.59	87.82	87.82
	70.69	70.68	70.69	70.80	70.80
0.125	660.48	70.72	186.34		
	186.82	186.81	186.82	187.05	187.05
	70.87	70.53	70.87	71.00	71.00
	87.02	86.23	87.02	96.40	96.40
	70.87	70.86	70.87	71.11	71.11
0.150	666.10	72.27	211.13		
	211.88	211.85	211.88	212.27	212.27
	71.06	70.60	71.06	71.21	71.21
	93.03	91.86	93.03	105.85	105.85
	71.14	71.11	71.14	71.54	71.54
0.200	678.31	76.38	258.78		
	260.26	260.19	260.26	261.14	261.14
	71.60	70.84	71.60	71.78	71.78
	106.42	104.38	106.42	126.65	126.65
	71.96	71.88	71.96	72.87	72.87
0.250	691.64	81.51	303.61		
	306.10	305.96	306.10	307.68	307.68
	72.38	71.24	72.38	72.59	72.59
	121.23	118.22	121.23	149.18	149.18
	73.18	73.02	73.18	74.89	74.89
0.375	728.05	97.36	402.18		
	408.18	407.74	408.18	412.40	412.40
	75.55	73.01	75.55	75.80	75.80
	161.67	156.14	161.67	208.33	208.33
	78.33	77.81	78.33	83.47	83.47
0.500	764.88	115.49	480.74		
	490.96	490.14	490.96	498.60	498.60
	80.55	75.97	80.55	80.79	80.79
	201.94	194.08	201.94	264.49	264.49
	86.72	85.57	86.72	97.58	97.58
0.625	797.85	133.99	540.59		
	554.82	553.60	554.82	565.86	565.86
	87.26	80.11	87.26	87.46	87.46
	237.69	227.92	237.69	312.70	312.70
	98.22	96.18	98.22	116.99	116.99
0.750	824.76	151.50	584.61		
	602.10	600.53	602.10	616.04	616.04
	95.32	85.25	95.32	95.46	95.46
	267.37	256.13	267.37	351.86	351.86
	112.19	109.05	112.19	140.54	140.54
0.875	845.40	167.28	616.21		
	636.11	634.27	636.11	652.35	652.35
	104.28	91.13	104.28	104.34	104.34

	291.30	278.94	291.30	383.04	383.04
	127.76	123.39	127.76	166.58	166.58
1.000	860.69	181.13	638.59		
	660.24	658.18	660.24	678.31	678.31
	113.68	97.52	113.68	113.66	113.66
	310.57	297.32	310.57	407.99	407.99
	144.04	138.41	144.04	193.41	193.41
1.250	880.24	203.65	665.77		
	689.79	687.39	689.79	710.69	710.69
	132.40	110.92	132.40	132.26	132.26
	339.47	324.93	339.47	445.29	445.29
	176.01	167.98	176.01	244.15	244.15
1.500	891.53	221.03	680.45		
	706.11	703.44	706.11	729.23	729.23
	149.60	124.14	149.60	149.39	149.39
	360.52	345.06	360.52	471.96	471.96
	204.43	194.46	204.43	286.11	286.11
1.750	898.89	234.93	689.53		
	716.47	713.58	716.47	741.29	741.29
	164.56	136.47	164.56	164.34	164.34
	376.76	360.65	376.76	491.54	491.54
	228.02	216.66	228.02	317.79	317.79
2.000	904.12	246.25	695.88		
	723.83	720.77	723.83	749.78	749.78
	177.18	147.56	177.18	176.98	176.98
	389.49	372.97	389.49	505.76	505.76
	246.81	234.55	246.81	340.42	340.42
2.500	910.84	263.02	704.20		
	733.46	730.19	733.46	760.38	760.38
	196.18	165.61	196.18	196.08	196.08
	407.02	390.17	407.02	522.96	522.96
	272.46	259.43	272.46	366.68	366.68
3.000	914.46	273.93	708.97		
	738.83	735.49	738.83	765.82	765.82
	208.63	178.43	208.63	208.64	208.64
	417.06	400.25	417.06	531.21	531.21
	286.95	273.88	286.95	378.64	378.64
3.500	916.33	280.81	711.65		
	741.72	738.36	741.72	768.53	768.53
	216.54	187.02	216.54	216.63	216.63
	422.54	405.89	422.54	535.09	535.09
	294.82	281.93	294.82	384.05	384.05
4.000	917.29	285.05	713.13		
	743.23	739.88	743.23	769.87	769.87
	221.44	192.52	221.44	221.59	221.59
	425.46	408.95	425.46	536.91	536.91
	298.98	286.30	298.98	386.52	386.52
5.000	918.02	289.17	714.40		
	744.40	741.08	744.40	770.85	770.85
	226.23	198.07	226.23	226.45	226.45
	427.77	411.45	427.77	538.19	538.19
	302.29	289.89	302.29	388.21	388.21
6.000	918.21	290.63	714.79		
	744.71	741.40	744.71	771.10	771.10
	227.95	200.10	227.95	228.19	228.19
	428.38	412.14	428.38	538.50	538.50

	303.17	290.88	303.17	388.60	388.60
7.000	918.26	291.15	714.92		
	744.80	741.49	744.80	771.16	771.16
	228.55	200.82	228.55	228.80	228.80
	428.55	412.33	428.55	538.58	538.58
	303.40	291.16	303.40	388.70	388.70
8.000	918.27	291.32	714.95		
	744.81	741.51	744.81	771.17	771.17
	228.76	201.07	228.76	229.01	229.01
	428.59	412.38	428.59	538.59	538.59
	303.47	291.23	303.47	388.71	388.71

```
FIRE DIAMETER (FT)
       2.00

FIRE COMP DIMENSIONS (FT)   MAG DIMENSIONS (FT)
   LE    WI    HT             LE    WI    HT
  30.0  20.0  10.0           30.0  20.0  10.0

DIMENSIONS FOR ADJACENT COMPARTMENTS 2,3,4,5 & 6
  COMPW2  COMPL3  COMPW4  COMPH5  COMPH6
  15.00   15.00   15.00   10.00   10.00

FUEL COMBUSTION ENERGY (BTU/LB)
  20000.0
FRACTION OF ENERGY LOST BEFORE STIRRING
  0.00

DENSITIES (LB/FT^3)
 STEEL   AIR    COMB GAS
 490.1  0.0805  0.0900

SPECIFIC HEATS (BTU/LB-F)
 STEEL   AIR    COMB GAS
 0.118  0.240   0.335

WALL THICKNESSES (INCHES)
 FIRE COMP SURFACES 1,2,3,4,5 & 6
  0.500  0.500  0.500  0.500  0.500  0.500
 MAGAZINE SURFACES 2,3,4,5 & 6
         0.500  0.500  0.500  0.500  0.500
 ADJACENT COMPARTMENTS 2,3,4,5 & 6
         0.500  0.500  0.500  0.500  0.500

HEAT TRANSFER COEFFS IN FIRE COMP, IN MAG & ADJ
 COMPS, & OUTSIDE MAG & ADJ COMPS (BTU/FT^2-HR-F)
      COMP          MAG        OUTSIDE
      0.48          0.36         0.36


INPUT EMISSIVITY OF MAGAZINE GAS
0.230E+00

RADIATION ABSORPTION COEFF OF MAG GAS, 1/FT
0.100E-01


ORDNANCE DIAMETER (FT)
 1.000

DISTANCE FROM ORDNANCE AXIS TO DECK (FT)
 5.000

DISTANCE FROM ORDNANCE AXIS TO COMMON BULKHEAD(FT)
 1.000

DISTANCE FROM SELECTED POINT OF INTEREST ALONG
ORDNANCE AXIS TO EITHER SIDE BULKHEAD OF MAG (FT)
10.000

ORDNANCE SEGMENT ANGLE (DEGREES)
 15.000

NUMBER OF HORIZONTAL BULKHEAD SEGMENTS
 10

NUMBER OF VERTICAL BULKHEAD SEGMENTS
 16
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RADIANT ENERGY ABSORBED BY MAGAZINE GAS

FROM WALL NO.	TO WALL NO.	DISTANCE FEET	FRACTION ABSORBED
1	2	18.03	0.16496E+00
1	3	30.00	0.25918E+00
1	4	18.03	0.16496E+00
1	5	15.81	0.14625E+00
1	6	15.81	0.14625E+00
2	1	18.03	0.16496E+00
2	3	18.03	0.16496E+00
2	4	20.00	0.18127E+00
2	5	11.18	0.10578E+00
2	6	11.18	0.10578E+00
3	1	30.00	0.25918E+00
3	2	18.03	0.16496E+00
3	4	18.03	0.16496E+00
3	5	15.81	0.14625E+00
3	6	15.81	0.14625E+00
4	1	18.03	0.16496E+00
4	2	20.00	0.18127E+00
4	3	18.03	0.16496E+00
4	5	11.18	0.10578E+00
4	6	11.18	0.10578E+00
5	1	15.81	0.14625E+00
5	2	11.18	0.10578E+00
5	3	15.81	0.14625E+00
5	4	11.18	0.10578E+00
5	6	10.00	0.95163E-01
6	1	15.81	0.14625E+00
6	2	11.18	0.10578E+00
6	3	15.81	0.14625E+00
6	4	11.18	0.10578E+00
6	5	10.00	0.95163E-01

MAGAZINE VIEW FACTORS

FROM WALL NO.	TO WALL NO.	VIEW FACTOR
1	2	0.16169E+00
1	3	0.60331E-01
1	4	0.16169E+00
1	5	0.30814E+00
1	6	0.30814E+00
2	1	0.10780E+00
2	3	0.10780E+00
2	4	0.14641E+00
2	5	0.31900E+00
2	6	0.31900E+00
3	1	0.60331E-01
3	2	0.16169E+00
3	4	0.16169E+00
3	5	0.30814E+00
3	6	0.30814E+00
4	1	0.10780E+00
4	2	0.14641E+00
4	3	0.10780E+00
4	5	0.31900E+00
4	6	0.31900E+00
5	1	0.10271E+00
5	2	0.15950E+00
5	3	0.10271E+00
5	4	0.15950E+00
5	6	0.47558E+00
6	1	0.10271E+00
6	2	0.15950E+00
6	3	0.10271E+00

6	4	0.15950E+00
6	5	0.47558E+00

RADIATION FROM COMMON BULKHEAD ON ORDNANCE

THETA (ORDNANCE ANGLE)=ANGLE BETWEEN LINE PERPENDICULAR TO COMMON BULKHEAD THROUGH ORDNANCE AXIS AND LINE FROM ORDNANCE AXIS TO ORDNANCE SURFACE ELEMENT

FLUX=INCIDENT FLUX (BTU/FT^2-HR) ON ORDNANCE SURFACE AT ORDNANCE ANGLE THETA FOR INDICATED TEMPERATURE OF COMMON BULKHEAD

ENG=INCIDENT ENERGY PER UNIT TIME (BTU/HOUR) ON ORDNANCE SURFACE ELEMENT AT THETA FOR INDICATED TEMP OF COMMON BULKHEAD

THETA			
FLUX(400F)	FLUX(600F)	FLUX(800F)	FLUX(1000F)
ENG(400F)	ENG(600F)	ENG(800F)	ENG(1000F)
7.5			
0.740E+03	0.171E+04	0.341E+04	0.614E+04
0.968E+02	0.223E+03	0.446E+03	0.804E+03
22.5			
0.734E+03	0.169E+04	0.338E+04	0.609E+04
0.960E+02	0.222E+03	0.442E+03	0.798E+03
37.5			
0.711E+03	0.164E+04	0.327E+04	0.590E+04
0.930E+02	0.215E+03	0.429E+03	0.773E+03
52.5			
0.650E+03	0.150E+04	0.300E+04	0.540E+04
0.851E+02	0.196E+03	0.392E+03	0.707E+03
67.5			
0.550E+03	0.127E+04	0.253E+04	0.457E+04
0.720E+02	0.166E+03	0.332E+03	0.598E+03
82.5			
0.429E+03	0.990E+03	0.198E+04	0.356E+04
0.561E+02	0.130E+03	0.259E+03	0.466E+03
97.5			
0.301E+03	0.694E+03	0.139E+04	0.250E+04
0.394E+02	0.909E+02	0.181E+03	0.327E+03
112.5			
0.184E+03	0.425E+03	0.849E+03	0.153E+04
0.241E+02	0.557E+02	0.111E+03	0.200E+03
127.5			
0.908E+02	0.210E+03	0.418E+03	0.754E+03
0.119E+02	0.274E+02	0.548E+02	0.987E+02
142.5			
0.304E+02	0.701E+02	0.140E+03	0.252E+03
0.397E+01	0.917E+01	0.183E+02	0.330E+02
157.5			
0.217E+01	0.500E+01	0.999E+01	0.180E+02
0.284E+00	0.655E+00	0.131E+01	0.236E+01

```
      172.5
 0.000E+00  0.000E+00  0.000E+00  0.000E+00
 0.000E+00  0.000E+00  0.000E+00  0.000E+00

       -7.5
 0.740E+03  0.171E+04  0.341E+04  0.614E+04
 0.968E+02  0.223E+03  0.446E+03  0.804E+03

      -22.5
 0.734E+03  0.169E+04  0.338E+04  0.609E+04
 0.960E+02  0.222E+03  0.442E+03  0.798E+03

      -37.5
 0.711E+03  0.164E+04  0.327E+04  0.590E+04
 0.930E+02  0.215E+03  0.429E+03  0.773E+03

      -52.5
 0.650E+03  0.150E+04  0.300E+04  0.540E+04
 0.851E+02  0.196E+03  0.392E+03  0.707E+03

      -67.5
 0.550E+03  0.127E+04  0.253E+04  0.457E+04
 0.720E+02  0.166E+03  0.332E+03  0.598E+03

      -82.5
 0.429E+03  0.990E+03  0.198E+04  0.356E+04
 0.561E+02  0.130E+03  0.259E+03  0.466E+03

      -97.5
 0.301E+03  0.694E+03  0.139E+04  0.250E+04
 0.394E+02  0.909E+02  0.181E+03  0.327E+03

     -112.5
 0.184E+03  0.425E+03  0.849E+03  0.153E+04
 0.241E+02  0.557E+02  0.111E+03  0.200E+03

     -127.5
 0.908E+02  0.210E+03  0.418E+03  0.754E+03
 0.119E+02  0.274E+02  0.548E+02  0.987E+02

     -142.5
 0.304E+02  0.701E+02  0.140E+03  0.252E+03
 0.397E+01  0.917E+01  0.183E+02  0.330E+02

     -157.5
 0.217E+01  0.500E+01  0.999E+01  0.180E+02
 0.284E+00  0.655E+00  0.131E+01  0.236E+01

CALCULATED EMISSIVITY OF MAGAZINE GAS
     0.148E+00


  GAS & WALL TEMPS WITH TIME

          TEMP-F    TEMP-F    TEMP-F    TEMP-F    TEMP-F
 TIME
  HR
         FC GAS    MAG GAS   COM WALL
          2         3         4          5          6     # FC WALL
           2         3         4          5          6    # MAG WALL
            2         3         4          5          6   # ADJ C GAS
             2         3         4          5          6  # ADJ C WALL

 0.050    435.08     68.54     85.55
           85.60     85.60     85.60     85.61     85.61
```

	70.54	70.45	70.54	70.60	70.60
	71.65	71.61	71.65	72.23	72.23
	70.50	70.50	70.50	70.51	70.51
0.075	453.23	67.99	97.30		
	97.41	97.40	97.41	97.42	97.42
	70.57	70.43	70.57	70.65	70.65
	72.99	72.90	72.99	74.36	74.36
	70.52	70.52	70.52	70.54	70.54
0.100	459.04	67.82	109.26		
	109.44	109.43	109.44	109.48	109.48
	70.61	70.42	70.61	70.71	70.71
	74.80	74.61	74.80	77.23	77.23
	70.56	70.56	70.56	70.61	70.61
0.125	462.88	67.96	121.08		
	121.35	121.34	121.35	121.44	121.44
	70.66	70.41	70.66	70.79	70.79
	76.89	76.58	76.89	80.56	80.56
	70.63	70.62	70.63	70.72	70.72
0.150	466.48	68.33	132.69		
	133.08	133.07	133.08	133.23	133.23
	70.73	70.41	70.73	70.88	70.88
	79.16	78.70	79.16	84.20	84.20
	70.73	70.71	70.73	70.88	70.88
0.200	473.78	69.62	155.27		
	155.98	155.95	155.98	156.31	156.31
	70.91	70.45	70.91	71.11	71.11
	84.06	83.27	84.06	92.01	92.01
	71.02	70.99	71.02	71.35	71.35
0.250	481.30	71.42	176.94		
	178.07	178.02	178.07	178.66	178.66
	71.17	70.53	71.17	71.40	71.40
	89.30	88.14	89.30	100.33	100.33
	71.44	71.38	71.44	72.04	72.04
0.375	500.79	77.16	227.07		
	229.61	229.45	229.61	231.17	231.17
	72.16	70.99	72.16	72.48	72.48
	103.44	101.30	103.44	122.43	122.43
	73.11	72.94	73.11	74.79	74.79
0.500	520.61	83.76	271.25		
	275.62	275.31	275.62	278.55	278.55
	73.68	71.83	73.68	74.05	74.05
	118.48	115.31	118.48	145.42	145.42
	75.68	75.32	75.68	79.04	79.04
0.625	539.95	90.70	309.58		
	315.98	315.48	315.98	320.54	320.54
	75.71	73.03	75.71	76.12	76.12
	133.70	129.53	133.70	168.21	168.21
	79.13	78.51	79.13	84.79	84.79
0.750	558.12	97.69	342.34		
	350.83	350.13	350.83	357.13	357.13
	78.21	74.58	78.21	78.65	78.65
	148.51	143.39	148.51	189.98	189.98
	83.41	82.47	83.41	91.93	91.93
0.875	574.66	104.58	370.03		
	380.49	379.58	380.49	388.52	388.52
	81.11	76.44	81.11	81.56	81.56

	162.49	156.50	162.49	210.17	210.17
	88.40	87.08	88.40	100.29	100.29
1.000	589.33	111.23	393.20		
	405.43	404.34	405.43	415.08	415.08
	84.33	78.57	84.33	84.78	84.78
	175.39	168.63	175.39	228.51	228.51
	93.98	92.22	93.98	109.63	109.63
1.250	612.95	123.52	428.34		
	443.43	442.01	443.43	455.81	455.81
	91.41	83.41	91.41	91.84	91.84
	197.65	189.61	197.65	259.57	259.57
	106.28	103.56	106.28	130.11	130.11
1.500	629.90	134.26	452.18		
	469.30	467.63	469.30	483.77	483.77
	98.82	88.71	98.82	99.23	99.23
	215.52	206.50	215.52	283.97	283.97
	119.13	115.42	119.13	151.20	151.20
1.750	641.85	143.47	468.33		
	486.92	485.04	486.92	503.01	503.01
	106.09	94.14	106.09	106.48	106.48
	229.82	220.05	229.82	303.14	303.14
	131.62	126.96	131.62	171.17	171.17
2.000	650.36	151.31	479.44		
	499.13	497.10	499.13	516.52	516.52
	112.90	99.44	112.90	113.27	113.27
	241.35	231.01	241.35	318.30	318.30
	143.13	137.64	143.13	188.99	188.99
2.500	661.20	163.67	493.09		
	514.34	512.06	514.34	533.59	533.59
	124.58	109.08	124.58	124.94	124.94
	258.47	247.34	258.47	339.99	339.99
	162.27	155.52	162.27	216.79	216.79
3.000	667.56	172.64	500.87		
	523.14	520.70	523.14	543.50	543.50
	133.58	117.02	133.58	133.95	133.95
	270.09	258.50	270.09	353.72	353.72
	176.22	168.68	176.22	235.11	235.11
3.500	671.54	179.13	505.74		
	528.67	526.12	528.67	549.60	549.60
	140.25	123.24	140.25	140.65	140.65
	277.95	266.13	277.95	362.29	362.29
	185.90	177.94	185.90	246.54	246.54
4.000	674.07	183.78	508.91		
	532.23	529.63	532.23	553.42	553.42
	145.09	127.93	145.09	145.51	145.51
	283.22	271.29	283.22	367.58	367.58
	192.44	184.27	192.44	253.49	253.49
5.000	676.72	189.39	512.35		
	536.03	533.39	536.03	557.30	557.30
	150.99	133.87	150.99	151.45	151.45
	288.99	277.03	288.99	372.81	372.81
	199.64	191.37	199.64	260.22	260.22
6.000	677.78	192.11	513.82		
	537.60	534.94	537.60	558.81	558.81
	153.89	136.90	153.89	154.38	154.38
	291.43	279.51	291.43	374.76	374.76

	202.71	194.46	202.71	262.67	262.67
7.000	678.20	193.41	514.45		
	538.23	535.58	538.23	559.39	559.39
	155.28	138.38	155.28	155.78	155.78
	292.45	280.56	292.45	375.49	375.49
	203.99	195.78	203.99	263.58	263.58
8.000	678.37	194.01	514.72		
	538.49	535.84	538.49	559.62	559.62
	155.94	139.08	155.94	156.44	156.44
	292.86	281.00	292.86	375.78	375.78
	204.52	196.33	204.52	263.92	263.92

```
FIRE DIAMETER (FT)
       1.00

FIRE COMP DIMENSIONS (FT)   MAG DIMENSIONS (FT)
    LE    WI    HT             LE    WI    HT
   30.0  20.0  10.0           30.0  20.0  10.0

DIMENSIONS FOR ADJACENT COMPARTMENTS 2,3,4,5 & 6
  COMPW2  COMPL3  COMPW4  COMPH5  COMPH6
  15.00   15.00   15.00   10.00   10.00

FUEL COMBUSTION ENERGY (BTU/LB)
   20000.0
FRACTION OF ENERGY LOST BEFORE STIRRING
  0.00

DENSITIES (LB/FT^3)
 STEEL   AIR   COMB GAS
 490.1  0.0805  0.0900

SPECIFIC HEATS (BTU/LB-F)
 STEEL   AIR   COMB GAS
 0.118  0.240   0.335

WALL THICKNESSES (INCHES)
 FIRE COMP SURFACES 1,2,3,4,5 & 6
  0.500  0.500  0.500  0.500  0.500  0.500
 MAGAZINE SURFACES 2,3,4,5 & 6
         0.500  0.500  0.500  0.500  0.500
 ADJACENT COMPARTMENTS 2,3,4,5 & 6
         0.500  0.500  0.500  0.500  0.500

HEAT TRANSFER COEFFS IN FIRE COMP, IN MAG & ADJ
 COMPS, & OUTSIDE MAG & ADJ COMPS (BTU/FT^2-HR-F)
       COMP          MAG          OUTSIDE
       0.48          0.36          0.36


INPUT EMISSIVITY OF MAGAZINE GAS
0.230E+00

RADIATION ABSORPTION COEFF OF MAG GAS, 1/FT
0.100E-01


ORDNANCE DIAMETER (FT)
 1.000

DISTANCE FROM ORDNANCE AXIS TO DECK (FT)
 5.000

DISTANCE FROM ORDNANCE AXIS TO COMMON BULKHEAD(FT)
 1.000

DISTANCE FROM SELECTED POINT OF INTEREST ALONG
ORDNANCE AXIS TO EITHER SIDE BULKHEAD OF MAG (FT)
10.000

ORDNANCE SEGMENT ANGLE (DEGREES)
 15.000

NUMBER OF HORIZONTAL BULKHEAD SEGMENTS
 10

NUMBER OF VERTICAL BULKHEAD SEGMENTS
 16
```

RADIANT ENERGY ABSORBED BY MAGAZINE GAS

FROM WALL NO.	TO WALL NO.	DISTANCE FEET	FRACTION ABSORBED
1	2	18.03	0.16496E+00
1	3	30.00	0.25918E+00
1	4	18.03	0.16496E+00
1	5	15.81	0.14625E+00
1	6	15.81	0.14625E+00
2	1	18.03	0.16496E+00
2	3	18.03	0.16496E+00
2	4	20.00	0.18127E+00
2	5	11.18	0.10578E+00
2	6	11.18	0.10578E+00
3	1	30.00	0.25918E+00
3	2	18.03	0.16496E+00
3	4	18.03	0.16496E+00
3	5	15.81	0.14625E+00
3	6	15.81	0.14625E+00
4	1	18.03	0.16496E+00
4	2	20.00	0.18127E+00
4	3	18.03	0.16496E+00
4	5	11.18	0.10578E+00
4	6	11.18	0.10578E+00
5	1	15.81	0.14625E+00
5	2	11.18	0.10578E+00
5	3	15.81	0.14625E+00
5	4	11.18	0.10578E+00
5	6	10.00	0.95163E-01
6	1	15.81	0.14625E+00
6	2	11.18	0.10578E+00
6	3	15.81	0.14625E+00
6	4	11.18	0.10578E+00
6	5	10.00	0.95163E-01

MAGAZINE VIEW FACTORS

FROM WALL NO.	TO WALL NO.	VIEW FACTOR
1	2	0.16169E+00
1	3	0.60331E-01
1	4	0.16169E+00
1	5	0.30814E+00
1	6	0.30814E+00
2	1	0.10780E+00
2	3	0.10780E+00
2	4	0.14641E+00
2	5	0.31900E+00
2	6	0.31900E+00
3	1	0.60331E-01
3	2	0.16169E+00
3	4	0.16169E+00
3	5	0.30814E+00
3	6	0.30814E+00
4	1	0.10780E+00
4	2	0.14641E+00
4	3	0.10780E+00
4	5	0.31900E+00
4	6	0.31900E+00
5	1	0.10271E+00
5	2	0.15950E+00
5	3	0.10271E+00
5	4	0.15950E+00
5	6	0.47558E+00
6	1	0.10271E+00
6	2	0.15950E+00
6	3	0.10271E+00

6	4	0.15950E+00
6	5	0.47558E+00

RADIATION FROM COMMON BULKHEAD ON ORDNANCE

THETA (ORDNANCE ANGLE)=ANGLE BETWEEN LINE PERPENDICULAR TO COMMON BULKHEAD THROUGH ORDNANCE AXIS AND LINE FROM ORDNANCE AXIS TO ORDNANCE SURFACE ELEMENT

FLUX=INCIDENT FLUX (BTU/FT^2-HR) ON ORDNANCE SURFACE AT ORDNANCE ANGLE THETA FOR INDICATED TEMPERATURE OF COMMON BULKHEAD

ENG=INCIDENT ENERGY PER UNIT TIME (BTU/HOUR) ON ORDNANCE SURFACE ELEMENT AT THETA FOR INDICATED TEMP OF COMMON BULKHEAD

THETA			
FLUX(400F)	FLUX(600F)	FLUX(800F)	FLUX(1000F)
ENG(400F)	ENG(600F)	ENG(800F)	ENG(1000F)
7.5			
0.740E+03	0.171E+04	0.341E+04	0.614E+04
0.968E+02	0.223E+03	0.446E+03	0.804E+03
22.5			
0.734E+03	0.169E+04	0.338E+04	0.609E+04
0.960E+02	0.222E+03	0.442E+03	0.798E+03
37.5			
0.711E+03	0.164E+04	0.327E+04	0.590E+04
0.930E+02	0.215E+03	0.429E+03	0.773E+03
52.5			
0.650E+03	0.150E+04	0.300E+04	0.540E+04
0.851E+02	0.196E+03	0.392E+03	0.707E+03
67.5			
0.550E+03	0.127E+04	0.253E+04	0.457E+04
0.720E+02	0.166E+03	0.332E+03	0.598E+03
82.5			
0.429E+03	0.990E+03	0.198E+04	0.356E+04
0.561E+02	0.130E+03	0.259E+03	0.466E+03
97.5			
0.301E+03	0.694E+03	0.139E+04	0.250E+04
0.394E+02	0.909E+02	0.181E+03	0.327E+03
112.5			
0.184E+03	0.425E+03	0.849E+03	0.153E+04
0.241E+02	0.557E+02	0.111E+03	0.200E+03
127.5			
0.908E+02	0.210E+03	0.418E+03	0.754E+03
0.119E+02	0.274E+02	0.548E+02	0.987E+02
142.5			
0.304E+02	0.701E+02	0.140E+03	0.252E+03
0.397E+01	0.917E+01	0.183E+02	0.330E+02
157.5			
0.217E+01	0.500E+01	0.999E+01	0.180E+02
0.284E+00	0.655E+00	0.131E+01	0.236E+01

```
           172.5
      0.000E+00  0.000E+00  0.000E+00  0.000E+00
      0.000E+00  0.000E+00  0.000E+00  0.000E+00

           -7.5
      0.740E+03  0.171E+04  0.341E+04  0.614E+04
      0.968E+02  0.223E+03  0.446E+03  0.804E+03

          -22.5
      0.734E+03  0.169E+04  0.338E+04  0.609E+04
      0.960E+02  0.222E+03  0.442E+03  0.798E+03

          -37.5
      0.711E+03  0.164E+04  0.327E+04  0.590E+04
      0.930E+02  0.215E+03  0.429E+03  0.773E+03

          -52.5
      0.650E+03  0.150E+04  0.300E+04  0.540E+04
      0.851E+02  0.196E+03  0.392E+03  0.707E+03

          -67.5
      0.550E+03  0.127E+04  0.253E+04  0.457E+04
      0.720E+02  0.166E+03  0.332E+03  0.598E+03

          -82.5
      0.429E+03  0.990E+03  0.198E+04  0.356E+04
      0.561E+02  0.130E+03  0.259E+03  0.466E+03

          -97.5
      0.301E+03  0.694E+03  0.139E+04  0.250E+04
      0.394E+02  0.909E+02  0.181E+03  0.327E+03

         -112.5
      0.184E+03  0.425E+03  0.849E+03  0.153E+04
      0.241E+02  0.557E+02  0.111E+03  0.200E+03

         -127.5
      0.908E+02  0.210E+03  0.418E+03  0.754E+03
      0.119E+02  0.274E+02  0.548E+02  0.987E+02

         -142.5
      0.304E+02  0.701E+02  0.140E+03  0.252E+03
      0.397E+01  0.917E+01  0.183E+02  0.330E+02

         -157.5
      0.217E+01  0.500E+01  0.999E+01  0.180E+02
      0.284E+00  0.655E+00  0.131E+01  0.236E+01

CALCULATED EMISSIVITY OF MAGAZINE GAS
      0.148E+00


 GAS & WALL TEMPS WITH TIME

          TEMP-F     TEMP-F     TEMP-F     TEMP-F     TEMP-F
 TIME
  HR
         FC GAS     MAG GAS    COM WALL
          2          3          4          5          6      # FC WALL
           2          3          4          5          6    # MAG WALL
            2          3          4          5          6   # ADJ C GAS
             2          3          4          5          6 # ADJ C WALL

 0.050    192.75     68.39      74.60
            74.65      74.65      74.65      74.65      74.65
```

	70.53	70.45	70.53	70.59	70.59
	70.97	70.94	70.97	71.18	71.18
	70.50	70.50	70.50	70.50	70.50
0.075	213.24	67.55	77.13		
	77.21	77.21	77.21	77.22	77.22
	70.54	70.42	70.54	70.63	70.63
	71.21	71.17	71.21	71.59	71.59
	70.50	70.50	70.50	70.51	70.51
0.100	223.37	66.95	79.95		
	80.08	80.08	80.08	80.09	80.09
	70.55	70.39	70.55	70.66	70.66
	71.56	71.51	71.56	72.17	72.17
	70.50	70.50	70.50	70.52	70.52
0.125	228.74	66.54	82.89		
	83.06	83.06	83.06	83.09	83.09
	70.56	70.36	70.56	70.70	70.70
	72.00	71.92	72.00	72.88	72.88
	70.52	70.51	70.52	70.54	70.54
0.150	232.02	66.28	85.85		
	86.08	86.08	86.08	86.12	86.12
	70.57	70.33	70.57	70.73	70.73
	72.49	72.38	72.49	73.68	73.68
	70.53	70.53	70.53	70.57	70.57
0.200	236.39	66.11	91.72		
	92.07	92.06	92.07	92.15	92.15
	70.60	70.27	70.60	70.80	70.80
	73.55	73.37	73.55	75.40	75.40
	70.59	70.58	70.59	70.67	70.67
0.250	239.95	66.23	97.42		
	97.92	97.91	97.92	98.06	98.06
	70.64	70.22	70.64	70.89	70.89
	74.66	74.40	74.66	77.20	77.20
	70.67	70.66	70.67	70.81	70.81
0.375	248.28	67.19	110.96		
	111.90	111.87	111.90	112.25	112.25
	70.80	70.16	70.80	71.14	71.14
	77.52	77.05	77.52	81.84	81.84
	70.99	70.96	70.99	71.35	71.35
0.500	256.25	68.54	123.48		
	124.95	124.88	124.95	125.60	125.60
	71.05	70.18	71.05	71.47	71.47
	80.46	79.76	80.46	86.58	86.58
	71.47	71.40	71.47	72.15	72.15
0.625	263.85	69.99	135.05		
	137.08	136.97	137.08	138.11	138.11
	71.38	70.29	71.38	71.87	71.87
	83.42	82.50	83.42	91.35	91.35
	72.09	71.97	72.09	73.18	73.18
0.750	271.08	71.47	145.71		
	148.35	148.19	148.35	149.81	149.81
	71.79	70.46	71.79	72.33	72.33
	86.39	85.26	86.39	96.10	96.10
	72.84	72.66	72.84	74.42	74.42
0.875	277.92	72.95	155.52		
	158.79	158.57	158.79	160.73	160.73
	72.26	70.70	72.26	72.86	72.86

	89.35	87.99	89.35	100.81	100.81
	73.70	73.46	73.70	75.84	75.84
1.000	284.37	74.41	164.54		
	168.45	168.17	168.45	170.90	170.90
	72.80	71.00	72.80	73.43	73.43
	92.26	90.69	92.26	105.43	105.43
	74.65	74.34	74.65	77.42	77.42
1.250	296.10	77.25	180.43		
	185.58	185.18	185.58	189.09	189.09
	74.00	71.75	74.00	74.69	74.69
	97.91	95.93	97.91	114.34	114.34
	76.79	76.31	76.79	80.96	80.96
1.500	306.35	79.96	193.79		
	200.11	199.58	200.11	204.68	204.68
	75.33	72.64	75.33	76.07	76.07
	103.25	100.88	103.25	122.68	122.68
	79.14	78.48	79.14	84.87	84.87
1.750	315.21	82.51	205.03		
	212.39	211.74	212.39	217.97	217.97
	76.74	73.62	76.74	77.50	77.50
	108.21	105.49	108.21	130.35	130.35
	81.62	80.77	81.62	88.97	88.97
2.000	322.83	84.89	214.46		
	222.75	221.99	222.75	229.25	229.25
	78.17	74.67	78.17	78.95	78.95
	112.77	109.73	112.77	137.35	137.35
	84.15	83.10	84.15	93.14	93.14
2.500	334.91	89.14	229.04		
	238.84	237.89	238.84	246.89	246.89
	80.99	76.82	80.99	81.78	81.78
	120.69	117.11	120.69	149.31	149.31
	89.09	87.65	89.09	101.23	101.23
3.000	343.70	92.70	239.39		
	250.31	249.21	250.31	259.55	259.55
	83.58	78.89	83.58	84.38	84.38
	127.11	123.11	127.11	158.83	158.83
	93.61	91.83	93.61	108.52	108.52
3.500	350.11	95.63	246.81		
	258.55	257.34	258.55	268.71	268.71
	85.87	80.78	85.87	86.67	86.67
	132.25	127.93	132.25	166.28	166.28
	97.54	95.47	97.54	114.74	114.74
4.000	354.82	98.02	252.18		
	264.55	263.25	264.55	275.38	275.38
	87.81	82.43	87.81	88.61	88.61
	136.32	131.74	136.32	172.06	172.06
	100.85	98.54	100.85	119.85	119.85
5.000	360.90	101.49	259.06		
	272.24	270.82	272.24	283.95	283.95
	90.76	85.01	90.76	91.56	91.56
	142.03	137.11	142.03	179.92	179.92
	105.74	103.10	105.74	127.16	127.16
6.000	364.32	103.69	262.91		
	276.56	275.07	276.56	288.74	288.74
	92.70	86.76	92.70	93.50	93.50
	145.50	140.39	145.50	184.51	184.51

	108.86	106.02	108.86	131.56	131.56
7.000	366.28	105.06	265.11		
	279.03	277.51	279.03	291.45	291.45
	93.93	87.90	93.93	94.74	94.74
	147.58	142.37	147.58	187.16	187.16
	110.77	107.82	110.77	134.15	134.15
8.000	367.41	105.91	266.40		
	280.47	278.92	280.47	293.01	293.01
	94.70	88.62	94.70	95.51	95.51
	148.81	143.55	148.81	188.68	188.68
	111.93	108.92	111.93	135.64	135.64

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